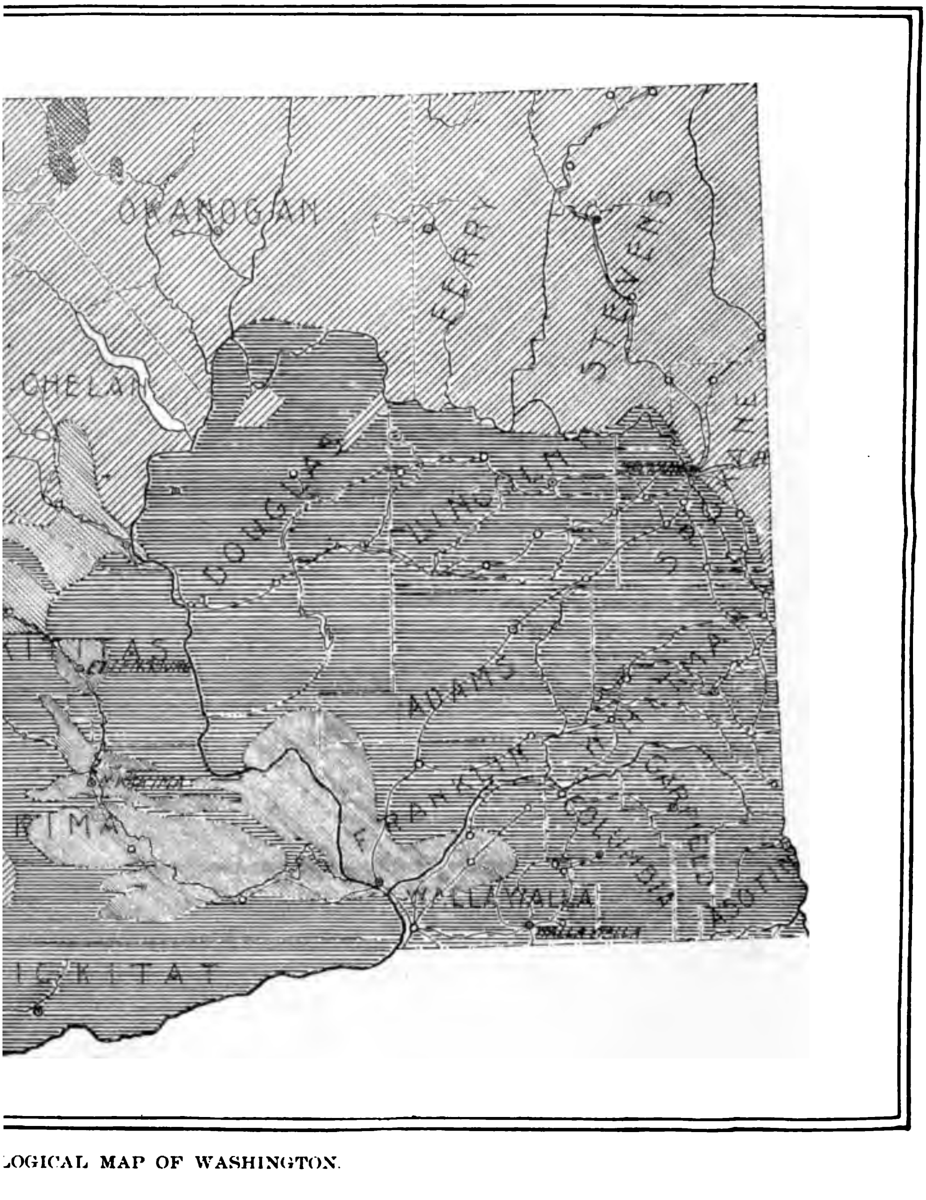

...LOGICAL MAP OF WASHINGTON.

WASHINGTON (State)

GEOLOGICAL SURVEY.

HENRY LANDES, STATE GEOLOGIST.

VOLUME I.

ANNUAL REPORT FOR 1901.

IN SIX PARTS.

PART I.

CREATION OF A STATE GEOLOGICAL SURVEY.

AND

AN OUTLINE OF THE GEOLOGY OF WASHINGTON.

BY
HENRY LANDES.

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Late Professor of Mining Engineering and Metallurgy, University of Washington.

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In the Creation of a State Geological Survey, after some mention is made of the causes leading up to the inauguration of a Survey, a copy of the law is then given. This law is modeled after that of older states where geological surveys have been in progress, and emphasizes the economic rather than any other side of geology. Some mention is also made of the organization of the Board of Geological Survey and the selection of a survey staff to whom the actual work of the Survey is entrusted. An account of the field work of the first season is included, together with some statements concerning the office work of the State Geologist, and a word in regard to the expenses of the Survey.

In An Outline of the Geology of Washington a resume is given of the present knowledge of the geology of the state. It is planned to afford a sort of bird's-eye view of the topography and the geological formations, in order that the detailed work of the future may be planned with intelligence. It will require many years of patient work before the geology of the state will be known in detail, and at the present time our knowledge of the subject is of a very general nature. It is thought worth the while to include a map upon which an attempt has been made to outline the larger geological formations. The boundaries of the different formations have, as a rule, been accurately determined only in a few places, and between these points the lines of separation are mainly conjectural. Nevertheless it is believed that the geological map will prove of help to all those whose work brings them in contact with the state's geology.

CREATION OF A STATE GEOLOGICAL SURVEY.

INTRODUCTION.

In her gifts to the State of Washington, Nature has been exceedingly generous. She has endowed the young commonwealth with resources many and varied, and already our citizens are coming to a realization of the material wealth which surrounds them. The fertile soil with which a large portion of the state is blessed is leading to a great development along agricultural lines; the extensive and magnificent forests of evergreens are conducive to lumbering and manufacturing on a large scale; the many fine harbors, advantageously located, point to a large and increasing commerce; the waters teeming with fish hold within their depths great riches; while the large mountainous area in which useful and precious metals abound contains in itself enough to make Washington a wealthy state, if correct and accurate knowledge of its mineral resources is made accessible to the public. In order that these resources lying hidden in the earth may be made known to our own citizens, and to any others who may wish to take a part in the building up of the state, it is necessary that a careful and systematic study should be made of our economic minerals. Thus it came about that, in response to a general demand of those interested in the development of the mineral resources of the state, the Legislature of 1901 passed a law providing for a Geological Survey of Washington, and appropriated money for the carrying on of the same. Following the plans of some of the older states in which geological surveys have been of great utility and benefit it was provided that the work of the survey for the present at least should be as practical as possible; that the economic minerals should be studied first of all; and that the results of the survey work should be embodied in reports and bulletins from time to time and disseminated among the people.

THE LAW ESTABLISHING THE SURVEY.

Be it enacted by the Legislature of the State of Washington:

SECTION 1. There is hereby established a State Geological Survey of the State of Washington, which shall be under the direction of the Board of Geological Survey of the State of Washington, which is hereby established, composed of the Governor, the Lieutenant Governor, the State Treasurer, the President of the University of Washington, and the President of the Washington Agricultural College and School of Science, who shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties, and the said board shall have general charge of the survey, and shall appoint as superintendent of the survey a geologist of established reputation, to be known as the State Geologist, and upon his nomination such assistants and employes as the said board may deem necessary, and the said board shall also determine the compensation of all persons employed by the survey, and may remove them at will.

SEC. 2. The said survey shall have for its object:

(1) An examination of the economic products of the state, viz., the gold, silver, copper, lead, and iron ores, as well as building stones, clays, coal and all mineral substances of value.

(2) An examination and classification of the soils, and the study of their adaptability to particular crops.

(3) The investigation and report upon water supplies, artesian wells, the water power of the state, gauging the streams, etc., with reference to their application for irrigation and other purposes.

(4) An examination and report upon the occurrence of different road building material.

(5) An examination of the physical features of the state with reference to their practical bearing upon the occupations of the people.

(6) The preparation of special geological and economic maps to illustrate the resources of the state.

(7) The preparation of special reports with necessary illustrations and maps, which shall embrace both the general and detailed description of the geology and natural resources of the state.

(8) The consideration of such other kindred scientific and economic questions as in the judgment of the board shall be deemed of value to the people of the state.

SEC. 3. The board shall cause to be prepared a report to the Legislature before each regular meeting of the same, showing the progress and condition of the survey, together with such other information as they may deem necessary and useful or as the Legislature may require.

SEC. 4. The regular and special reports of the survey, with proper illustrations and maps, shall be printed as the board may direct, and the reports shall be distributed or sold by the said board as the interests of the state and of science demand; and all money obtained by the sale of the reports shall be paid into the state treasury.

SEC. 5. All materials collected, after having served the purpose of the survey, shall be distributed by the board to the University of Washington, the Washington Agricultural College and School of Science, the normal schools, and the leading high schools of the state in such a manner as to be of the greatest advantage to the educational interests of the state.

SEC. 6. The Board of Geological Survey shall meet for organization within thirty days after the passage of this act. The regular meetings of the board shall be held on the first Wednesday in April and the first Wednesday in November of each year.

SEC. 7. The sum of five thousand dollars ($5,000) annually, or so much thereof as may be necessary, is hereby appropriated out of any funds out of the treasury not otherwise appropriated for the purpose of carrying out the provisions of this act.

SEC. 8. "An act to create a mining bureau, and to define its powers and duties, and declaring an emergency," approved February 25, 1890; also "An act to create the office of a State Geologist, prescribing his duties and compensation, and making an appropriation for the same, and declaring an emergency," approved February 28, 1890, are hereby repealed.

ORGANIZATION OF THE BOARD OF GEOLOGICAL SURVEY.

In accordance with the law, and at the call of the Governor, the following gentlemen: Governor Rogers, Lieutenant Governor McBride, State Treasurer Maynard, President Graves of the University of Washington, and President Bryan of the

Agricultural College and School of Science, met upon June 5, 1901, at Tacoma, and organized the Board of Geological Survey of the State of Washington. Permanent organization was effected by electing Governor Rogers as president of the Board, and State Treasurer Maynard as its secretary.

The first important business of the board was the selection of the survey staff. Professor Henry Landes, of the University of Washington, was chosen State Geologist, with Professors Solon Shedd and W. S. Thyng, of the Agricultural College and School of Science, and D. A. Lyon of the University of Washington, as geologists. Charles E. Gaches, George W. Evans, Louis Pohle and Lewis D. Ryan were appointed field assistants for the season of 1901.

The board voted that members of the survey staff should receive no salaries other than a small *per diem* allowance for time actually spent in the field work of the survey. The president and the secretary of the board were authorized to pass upon the accounts of the State Geologist and to draw upon the State Auditor for the payment of the bills approved by them.

FIELD WORK OF 1901.

In order that the citizens of the state may be informed as to what the survey attempted to do in its first field season, the general scheme of the summer's work is here set forth and somewhat elaborated. It was thought advisable to do first of all such field work as would be required in order to prepare a general statement of the mineral resources of the state. With this end in view, the major part of the season was spent in reconnaissance work, studying the geological formations, examing the mines of gold, silver and copper, making maps and sections of the coal fields, examining with care the building and ornamental stones, and collecting other data for the first report, which should be devoted chiefly to a description of the state's mineral resources. It was also planned to gather such data during the first season as would be needed in the preparation of some special bulletins on the coal fields, building and ornamental stones, clay materials, and on one or two of the most prominent mining districts of the state. In order to carry on the plans outlined above, three parties were placed in the field. These were equipped so that they might move with as great

rapidity as possible and thus be able to cover a large part of the state in the time at their disposal. Necessarily the work was of a reconnaissance order, and only a little attention could be given to details. The personnel and scope of work of the three parties will now be mentioned.

The first party was composed of the State Geologist, D. A. Lyon, C. E. Gilman, Lewis Ryan, Charles Landes and J. W. P. Dunlap. About July 1st, after having provided themselves with the necessary horses and camp equipment, they began work at Republic. Here they remained about ten days, studying the mining geology of the district. The party then proceeded north to Curlew, visiting several properties on the way. The next move was to the Myers creek district and thence to Oroville and Loomis. At the latter place some time was spent visiting and studying the best developed mines in the Palmer mountain district. From this point the party proceeded to the Methow by way of Conconully. From the Methow they moved up the Twisp river, over Twisp pass to Bridge creek, and down the Stehekin to the head of Lake Chelan. From this point the mines on Railroad creek were visited. From Lake Chelan the party passed to the Horseshoe basin, thence over Cascade pass and down the Skagit to Marblemount. Barron was next visited and an examination was made of the mines on Slate and Thunder creeks and thereabouts. Returning down the Skagit to Hamilton, some time was spent in studying the coal field of that region. The boundaries of this field were approximately determined, as were those of the Cokedale field as well. Blue Canyon was next visited, and here some time was spent in determining the boundaries of that large coal field, and in studying the outcrops of coal which occur at several places northward and eastward of Lake Whatcom. While the party were camped at Keese a detachment under the leadership of D. A. Lyon visited the principal mines of the Mount Baker district. The last move of the party was to LaConner where the horses were to winter, and here the work of the party closed for the season.

The second party, consisting of Professor Solon Shedd as geologist and George Evans and Louis Pohle as field assistants, spent the season mainly in an examination of the building and ornamental stones of the state, paying some attention to the clay materials as well. They began work at Spokane in the last

days of June by making an examination of the granite quarries about Spokane and Medical Lake. Then came an investigation of the marble and serpentine which is found at Valley station and elsewhere in Stevens county. Finishing their work here, they then moved to Western Washington, where the remainder of the summer was spent in a study of the building stones and clays of that region. Tenino, Wilkinson, Index, Chuckanut and Sucia Island were visited, as well as many other places where stone of desirable character for building purposes was known to exist.

Professor W. S. Thyng, who made studies upon several mining districts during the summer, began his work upon the mines in the districts about Silverton, Monte Cristo, Goat lake, Silver creek and Index. From Index he went to the Carbon river district to examine the copper mines located there. He finished his work by an examination of the Cedar canyon district in Stevens county.

OFFICE WORK.

It is a fact acknowledged by every one who has had any experience in the matter that the hardest and most exacting work of a Geological Survey is that of the office. It is here that the field notes must be most carefully elaborated, the minerals and rocks collected during the summer must be identified and described, and numerous analyses made of the same; maps and sections must be prepared for illustrating the subject matter of the bulletins and reports; and great care must be exercised in every direction in order that the reports may be complete and accurate in every respect.

Since the inauguration of the survey, a considerable portion of the time of the State Geologist has been taken in making replies to inquiries from our own citizens and from many outside the state, who desire information concerning our mineral resources. It is of course necessary that these replies be carefully prepared, so that the demands of our citizens and of outside capitalists may be fully met. While the correspondence has already reached large proportions, it will doubtless reach a greater volume when the fact that Washington has a Geological Survey becomes better known.

One important part of the work of the Geological Survey is the identification of minerals and rocks sent in by prospectors

and mining men. Such specimens will be examined and promptly reported upon if the following rules are observed: 1st. A specimen should weigh not less than one-half pound and should be taken from as great a depth as possible. 2d. Each specimen must be accompanied by a statement of the exact location where it is found, and a description of the mass as a whole from which it came. 3d. The specimen must be sent prepaid, with the name of the sender plainly written upon the package, and addressed to the State Geologist, University Station, Seattle, Washington.

It must be patent to every citizen that no assays or chemical analyses can be expected from the office of the State Geologist. In the first place no provision is made for any such work in the law creating the Geological Survey. In the second place the sampling or selection of ores for assays or analyses is of the greatest importance, and usually an average sample is not taken, so that the assay or analysis indicates very little as to the real value of the mineral deposit. In the third place the cost of making such assays or analyses by the survey would be so very great that its resources would be largely consumed in this work alone, and the sender only would be benefited and not the state.

EXPENSES OF THE GEOLOGICAL SURVEY.

The amount appropriated by the Legislature of 1901 for the carrying on of the work of the Geological Survey was five thousand dollars per annum. For all moneys paid out in the prosecution of the work of the survey vouchers are taken in duplicate. These vouchers pass through the hands of a committee of the Board of Geological Survey, and upon their approval one set passes to the State Auditor, while the duplicate set is retained by the board. The appropriation above mentioned must provide for the entire expenses of the survey, not only for the field work but for the printing of all reports and the mailing of the same.

The cost of doing field work in Washington is probably fully as great, if not greater, than that of any other state in the Union, because of the extreme ruggedness of large parts of the state and the difficulties in the way of transportation. It is, therefore, only by practicing the most rigid economy and by getting a large amount of work done without any attendant compensation that it is possible to attain even moderate results.

AN OUTLINE OF THE GEOLOGY OF WASHINGTON.

The following brief account of the geology of Washington must be regarded as general and at the same time provisional. It is thought desirable at this time to make some preliminary statements concerning the state as a whole, in order to pave the way for the detailed work of the future. Up to the present time it is only at a few points, often widely separated, that the geology of the state has been studied with thoroughness and with an attention to details. Not until all parts of the state have become readily accessible, and especially not until complete topographic maps have been made, will it be possible to carry on all of the investigations necessary to formulate a complete and detailed account of Washington geology.

The most important work on the geology of Washington has been done by the United States Geological Survey, mainly by Messrs. Bailey Willis, I. C. Russell, and George Otis Smith. In the Bibliography of Washington Geology, comprising part 6 of this volume, will be found a list of the contributions to the geology of the state that have been made by the above mentioned geologists and others. In the preparation of this article all printed reports on the geology of Washington that were accessible have been freely drawn upon, and an attempt has been made to give full credit in every case. The writer has been engaged for several seasons in geological field work in various parts of Washington, and much of the result of his work on the general geology of the state is embodied herein.

TOPOGRAPHY.

Before an intelligent discussion of the geology of Washington can be had, it is necessary that some statements concerning the topographic features of the state should be made. In time to

come, when the geology is better known than it is now, the topographic features as a result will be much better understood; and consequently, when topographic maps shall have been made of the entire state, the details of its geology will be made out with much greater ease than is possible at the present time.

A visitor to Washington cannot but be immediately impressed by the very great diversity of physical features which the state possesses. From the low plains which are found along the 3,000 miles or more of coast line it is possible within a short space of time to ascend to heights on which the snow remains throughout the year. The far reaching influence of such great differences in the topography of the state are readily observable. Not only is a varied scenery produced, but of necessity there follows a great variation in the climate, rainfall, soil, vegetation, and occupations of the people in the different topographic provinces of the state.

A study of the relief map which accompanies this report will make it clear that the physical features of the state may be divided into six provinces. Passing from the Pacific ocean inland these divisions are: Olympic Mountains, Puget Sound Basin, Cascade Mountains, Okanogan Highlands, Columbia Plain, and Blue Mountains. It must be understood, of course, that no hard and fast lines separate these provinces. The border line is always arbitrary and difficult of exact location. Another fact to be noted is that without exception these provinces extend beyond the boundaries of the state, overlapping into the adjoining states. The provinces already noted are capable of subdivision into smaller and yet smaller areas which can receive but scant attention in these pages.

OLYMPIC MOUNTAINS.

These mountains should be regarded as merely a segment of the general coastal range which extends northward and southward beyond the confines of the state. They reach their greatest development in Washington in the triangular shaped area bordered by the ocean, the Straits of Fuca and the arms of Puget sound. Their highest peak is Olympus, which has an elevation of about 8,000 feet, and is the first point of land to be recognized by navigators when approaching the coast of Washington from the westward. The Olympics when seen from any point of view exhibit a labyrinth of serrated ridges and sharp

peaks. Standing as they do in the path of the moist westerly winds, and rising to a considerable height above the sea, these mountains are visited by an excessive precipitation.

The Olympics have been but little explored and reliable information concerning them is very meager. It is known, however, that they are well nigh impassable because of their extremely broken and dissected character. The divides are exceedingly sharp and difficult to follow. The rivers flow in deep canyons with walls which in many instances can not be scaled. On the whole the streams of these mountains seem to be approaching the stage of maturity in their development.

The southern extension of the Olympics consists merely of hills or ridges rising as a rule not more than 1,500 feet above the sea. In fact so inconspicuous are they in the topography of the southwestern part of the state that the term mountains is not usually applied to them. They have been cut in two by the Chehalis and Columbia rivers.

PUGET SOUND BASIN.

The Puget Sound basin lies between the Olympic and Cascade mountains, its longer axis having a north and south direction. It has the form of a broad trough, its large central area being less than 100 feet above sea level, while its eastern and western sides rise gradually until they coalesce with the mountains.

The basin for the most part has a foundation of sedimentary rocks which have been thrown into folds. The inequalities produced by the folding of the strata have been largely reduced by erosion, so that the basin at the present time is a plain of low relief.

A late episode in the history of the basin was a subsidence of sufficient extent to cause the wide valleys of the northern portion to sink below sea level, whereby the rivers became "drowned" and Puget sound was produced. A still later episode was the advent of great glaciers from the mountains to the northward, eastward, and westward, whereby the northern part of the basin was overwhelmed and its rock foundation almost wholly hidden by a mantle of glacial sediments varying in thickness from 500 to 1,000 feet. The glacial sediments consist for the most part of plains of till, with local deposits of stratified clay, sand and gravel. About the southern end of Puget sound

there are many level, barren plains of coarse sand and gravel, which were formed by the great streams of water which the melting glaciers produced. The southern part of the basin has a somewhat more hilly or broken character than the northern part, because of an absence of plains of glacial materials.

CASCADE MOUNTAINS.

On the southern border of Washington where the Cascade mountains enter the state they have a breadth of about fifty miles, which increases to 100 miles at the British Columbia line. The general height of the mountains is about 8,000 feet above the sea, although there are some peaks, usually old volcanoes, which rise to much greater heights. Only one of the volcanoes that are well known stands on the axis of the range, viz., Glacier Peak. The remaining volcanoes, Baker, Rainier, and St. Helens, stand on the western flank of the mountains, and Adams on the eastern side.

The northern half of the Cascades in Washington differs much in character from the southern half. In the southern portion igneous activity has been very great and much of the topography is due to the presence of volcanoes with their attendant lava flows. In the northern Cascades there is such a marked uniformity in the heights of the loftier peaks and ridges as to suggest very strongly that they are the remnants of a plateau. In other words, the northern Cascades have seemingly been carved out of a great plateau which was the result of the uplifting of a peneplain. The ruggedness of the topography, therefore, is not due primarily to the folding of the rocks, but to erosion. The streams have been, and are yet, large and well fed, so that the old plateau is now well dissected and transformed into mountains of extreme ruggedness. The main streams which flow out from the Cascades all have valleys noted for their depths, so that the flanking mountains stand alongside in great boldness. In ascending the principal mountain valleys, especially those on the western side of the Cascades, one notices that the grade is gentle, even into the heart of the mountains, and the ascent is nearly all made in the last few miles before the summit is attained.

Very many glaciers, some of large size, occur in the higher portions of the Cascade mountains. They once filled the larger

mountain valleys and eroded and modified these very materially. Amphitheatres or cirques are found at the heads of many streams, and as these basins usually contain small lakes and parks, they afford some of the most beautiful scenery that the mountains possess.

OKANOGAN HIGHLANDS.

The Okanogan highlands occupy that portion of the state lying north of the Columbia and Spokane rivers and east of the Cascades. On their western border they merge insensibly into the latter mountains, and on the east they join the mountains of Idaho. In their geological characteristics they closely resemble the northern Cascades, but in their topographical aspects they are quite different. Instead of ruggedness they are characterized largely by beautiful rolling surfaces, with long gentle slopes leading down from the watersheds to the wide stream basins. The hills are low and broad and of a slope so slight that they are covered with a deep soil. The divides between the larger streams, although they reach heights of 5,000 or 6,000 feet above the sea, are gently rounding and not sharp or abrupt. The larger valleys were filled with glaciers at one time, and characteristic terraces or moraines are now found along the valley sides. Throughout the Okanogan highlands there is a close and easily observed relationship between the vegetation and the amount of rainfall. On the higher hills and ridges where the rainfall is greatest forests grow everywhere. On the lower hills and in the higher valleys the rainfall will not support a forest growth, but bunch grass grows luxuriantly. In the lower valleys of the larger streams, where the rainfall is least, bunch grass disappears and sage brush takes its place. The forests have an open character with practically no underbrush, the number of streams is large and the water excellent, so that the highlands have a remarkable park-like character.

COLUMBIA PLAIN.

With the exception of the Blue mountains, described below, virtually all of that part of the state south of the Okanogan highlands and east of the Cascade mountains is embraced in the Columbia plain. From the Columbia river at a height of 500 or 600 feet above the sea, the plain rises rather rapidly to the westward until it merges into the piedmont plateau which bor-

ders the Cascades. To the eastward the plain rises slowly and does not reach an altitude of 2,000 feet until near the Idaho line. The area under discussion is really composed of a number of plains and plateaus which can not be differentiated with accuracy at this time.

While the Columbia plain as a whole is quite level and monotonous, there are some local irregularities which tend to give the plain a diversified appearance. In the region about North Yakima there are a number of sharp east and west ridges of a semi-mountainous character, which represent anticlines or arches in the sheets of lava. These ridges have occasionally risen athwart the stream courses, and some rivers, such as the Yakima, have cut deep gaps across them. In some parts of the plain, notably within the great bend of the Columbia river, the country is much cut up by old river courses, now wholly abandoned by streams, and known locally as coulees. Of these, Moses and Grand coulees are good types. The coulees are often 500 or 600 feet in depth, with precipitous walls, and represent the courses of streams which have now sought other channels, or which have withered away because of a decrease in the amount of rainfall. Each coulee now has within it usually a chain of small alkali lakes.

In the region drained by the Snake river and its tributaries deep canyons have been cut in the plain. From the Snake river northward toward Spokane, in what is known as the Palouse country, the plain (or more properly called here a plateau) is covered with hills having altitudes of from 400 to 600 feet, which possess the character of sand dunes. They are hills of æolian origin, made up of deposits of fine soil which was carried to its present position by the prevailing winds of the southwest. These wind-blown hills have long, gentle southwesterly slopes, with northeasterly ones that are somewhat abrupt. They must have been formed at a time when there was less precipitation than now and when the surface of the country had no vegetation upon it. Since the time when the hills were fashioned out of the wind-blown soil the streams have accomplished considerable erosion, and now have their drainage lines well established.

BLUE MOUNTAINS.

These mountains, situated on the border line between Washington and Oregon, represent merely a local uplift of promi-

nence in the great lava plain. A broad, dome-shaped area of lava was elevated here, rising about 7,000 feet above the sea. and about 5,000 feet above the surrounding plain. While the streams have cut deep canyons in the mountains, as a whole they still retain their even-topped appearance. The mountains are high enough to have sufficient precipitation to support a moderate forest growth, and in this way they afford a contrast to the surrounding prairies.

GEOLOGICAL FORMATIONS.

METAMORPHIC ROCKS.

Metamorphic rocks are those which have been acted upon by heat and pressure for the most part and as a result they have undergone certain changes from their original conditions. These changes are so great that the rocks are greatly altered in their structure, mineral composition, and physical aspects. Some common examples of metamorphism are the changes of ordinary limestone into marble, sandstone into quartzite, and clay-rock into slate.

It is generally believed that the metamorphic rocks are the oldest as far as known in Washington, while at the same time all efforts to determine their geological age have so far been unsuccessful. From their marked physical resemblance to Archæan rocks found in other parts of the United States some have been inclined to designate the metamorphic rocks of Washington as Archæan, but this cannot be done with assurance until further evidence is obtained. In many places it has been observed that the metamorphic rocks have sedimentaries lying unconformably upon them, and in fact it has been largely from the erosion of the former that the latter have been made.

It is known that metamorphic rocks occupy a large portion of the state, being very frequently met with throughout the Cascades, from Stampede pass northward to the British Columbia boundary, and from near Puget Sound eastward across the Cascade mountains and Okanogan highlands to the Idaho line. The ordinary varieties of metamorphic rocks in Washington are gneiss, schist, marble, slate, and quartzite. The most important of these are described below.

Gneiss.

Gneiss is a rock composed essentially of the same minerals as granite, and as a consequence is often mistaken for the latter. While a hand specimen of gneiss usually resembles closely a hand specimen of granite, in a ledge of gneiss a banded or stratified appearance is always displayed. Gneiss in general is a good building stone, and in Washington it oftentimes has within it mineral veins of economic importance.

The gneiss of Washington is generally associated with granite and schist, usually lying above the former and below the latter. The most important areas of gneiss observed by the writer are the following: A wide belt, having a north and south course, which is crossed by the road from Myers Falls to Republic; along the Kettle river, between Curlew and Midway, where many veins of pegmatite occur in the gneiss; along the Okanogan river between Johnson creek and Oroville; at several points along the Methow river, between its mouth and the Twisp river, notably near the mouth of Gold creek; along Bridge creek and the Stehekin river, from Twisp pass to Lake Chelan; and on the Columbia river between Chelan Falls and Wenatche.

Schist.

Schists are metamorphic rocks, possessing a cleavage which causes them to break into thin laminæ or folia. The parting along the cleavage planes is almost always wavy, although occasionally it is smooth. When derived from a sedimentary rock the cleavage of schist is at right angles to the original stratification, although all semblance of the latter has usually been wholly destroyed by metamorphism. Schists are recognized by their cleavage habit and by the greasy feel which they usually possess.

Schists are of various kinds and are usually classified according to the prominent minerals found within them. Mica is usually the most abundant mineral and mica schists are therefore of the most frequent occurrence. Chlorite, hornblende, and staurolite, with some others, also occur occasionally and give rise to chlorite schist, hornblende schist, etc., etc.

Russell * mentions a number of localities herein given where schists occur. A great escarpment occurs on the south side of Yakima valley two miles southwest of Clealum. The schists

* Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, pp. 102-3-4, 1900.

may be traced westward from this point for ten or twelve miles, with an increasing thickness exposed. Similar schistose rocks outcrop about the base of the Wenatche mountains, at various localities at the head of the Teanaway and on Nigger creek, and thence northward to beyond Leavenworth on the Great Northern Railway.

The mountains west of the Columbia and on the north side of the Wenatche valley, known as the Entiat range, are composed largely of mica and hornblende schist. Here the schist is cut by dikes of basalt and acid dikes as well and in some places quartz veins are found containing free gold. Another exposure of schist, thought by Russell to be a continuation of the last mentioned area, occurs in the mountains to the northward of Lake Wenatche between Chiwahwah and White creeks. Hornblende schist also occurs in the vicinity of Dirty Run peak, near the western end of Lake Wenatche, and along the crest of the ridge which extends northwest from it for about ten miles. This same rock forms the south wall of the valley of the west fork of White creek, and extends to the main Cascade divide near Glacier peak. The valley of Indian creek is almost surrounded by schists, which also crown Indian pass and cover most of the country from the region along the Sauk river to the mouth of Whitechuck creek. Schist is found in the region around Cascade pass and along Cascade creek for nearly its entire length. The most northern area of schist recorded by Russell occurs on the Skagit, extending from the mouth of Skaadle to beyond the mouth of Beaver creek. On the east side of the valley of the Skagit the same schist outcrops from Thunder creek to a point five miles up Ruby creek. Russell * also mentions schist as occurring under the lava in the Snake river canyon between Grande Ronde river and Wild Goose creek, and in the mountains along the western base of which runs the Washington-Idaho line. On the Snake river, at Buffalo rock, fifteen miles above Asotin another outcrop of schist occurs.

Other considerable areas of schist have been observed by the writer, usually associated with gneiss. Schist occurs commonly along the Methow between its mouth and that of Twisp river. Schist with gneiss occurs on Bridge creek and on the Stehekin between Twisp pass and the head of Lake Chelan. It occurs

* **Russell: Water Supply and Irrigation Papers, U. S. Geol. Survey, No. 4; p. 86, 1897**

occasionally on the borders of Lake Chelan and between the mouth of Chelan river and Wenatche. Large areas of schist occur on the Skagit from near Marblemount to Cokedale.

Near Hamilton the schist contains some important veins of magnetic iron. West of Hamilton and about Cokedale are two areas where schist is the enclosing rock of some coal basins to be described later on. Upon the eastern and southern boundaries of the large Blue Canyon coal field mica schist constitutes the rim rock. Schist is found in isolated outcrops about La Conner. It also occurs on the Great Northern Railway near Madison, and for a number of miles from Berne to the eastward. Four miles east of Cheney along the Northern Pacific Railway there are several outcrops of mica schist where the overlying basalt, thin at this place, has been wholly removed.

Crystalline Limestone.

In the metamorphic area above described, crystalline limestone occurs in a large number of localities. Originally a common limestone, it has become crystalline or marbleized through the influence of heat and pressure which was at some time exerted upon it. From an economic standpoint the best crystalline limestone, as far as now known, occurs in Stevens county where commercial marble is found at several places and is extensively quarried. A long, narrow belt of limestone extends north and south across Ferry county, lying at the western foot of the granite divide which separates the Columbia and Kettle rivers from the streams to the westward. Near the head of Lambert creek and in the vicinity of the town of Curlew the limestone forms hills which show quite prominently because of their white color. Crystalline limestone occurs midway between Republic and Wauconda. It also occurs near Johnson creek on the Okanogan river and on the eastern slope of Palmer mountain. On the western slope of the Cascade mountains crystalline limestone occurs at many places from Snoqualmie Pass northward, notably near the Denny iron mines, along the Stillaguamish river near Granite Falls, along the Skagit river between Baker and Marblemount, and near Kendall in Whatcom county. Important areas of the same rock occur on the San Juan islands, where the limestone is intimately associated with some basic eruptive rocks. It occurs here in isolated masses varying in

YAKIMA CANYON, BETWEEN NORTH YAKIMA AND ELLLENSBURG.

size from a few feet in diameter to one-fourth of a mile or so. This limestone doubtless belonged to some sedimentary beds from which fragments were torn by the eruptive rocks in their ascent from their former position below the surface.

Quartzite.

Quartzite is a metamorphic rock which has been derived from sandstone by the cementing of the sand grains by silica. It is practically, therefore, entirely composed of silica, and is of course very hard and resistant.

In a country where gneiss, schist, and crystalline limestone occur it would be very exceptional if quartzite did not occur also. In Washington, however, as far as the metamorphic area has been studied, quartzite has been noted in only a few places. It has been observed by the writer on the Similkameen river, a few miles directly north of Loomis. It is here interstratified with beds of gneiss. Russell* mentions quartzite as occuring at several places north of the Snake river and near the Idaho line, where islands of quartzite appear in the sea of lava. Kamiack and Steptoe Buttes in Whitman county are two very prominent examples of quartzite. The first of these rises over 500 feet, and the second over 1,000 feet, above the surface of the surrounding basalt plateau.

IGNEOUS ROCKS.

The igneous or heat rocks are those which have solidified from a fused condition. An igneous rock may be formed by the fusion of a sedimentary rock, or it may represent merely the final stage in metamorphism. Two kinds of igneous rocks may be noted — the plutonic and the volcanic. The plutonic or deep seated rocks are those which, cooling at a distance beneath the surface and under great pressure, solidify slowly, attaining a coarse granular structure, except near their borders where they come in contact with the cooler rocks. In Washington the plutonic rocks are well represented by granite, syenite, diorite, etc., but as detailed studies have not been made in regard to the particular areas where these different varieties occur, it will be convenient to group them all under the head of granite.

Volcanic rocks are those which are brought to the surface or

*Russell: Water Supply and Irrigation Papers, U. S. Geol. Survey, No. 4, pp. 37-38, 1897.

near to the surface by volcanic action and are either spread out in layers, intruded into fissures as dikes, or accumulated as fragments of lava. On account of their sudden cooling, many volcanic rocks are glassy or only partly crystalline. Others are wholly crystalline, the crystals generally, but not always, being of a small size. Examples of volcanic rocks are to be found throughout Washington, notably the great lava plains of southeastern Washington, and within and about the great volcanoes of the Cascade mountains.

Granite.

Granite occurs at very many places and in very large quantities in Washington. Throughout the metamorphic area of the state above described granite is perhaps the most common rock. It is the belief of the writer that further study will make it clear that there are in the state two kinds of granite—one representing a final stage in metamorphism, or in other words, a metamorphic granite—the other variety an intrusive granite which was forced into the rocks above it. It is possible that these varieties are both shown along the line of the Great Northern Railway in the Cascade mountains. At Index a light colored granite occurs composed mainly of feldspar and quartz, with comparatively small amounts of mica and hornblende. Although the writer has observed this granite over a considerable area about Index, at no place has any evidence of intrusion been noted. At the point where the railway crosses the mountain summit there is another large area of granite, composed mainly of mica and hornblende with a proportionally small amount of quartz and feldspar. This granite is very plainly intrusive, for it shows within it embedded masses of mica schist which it broke off in its ascent.

Granite occurs about Spokane and Medical Lake, where important quarries have been developed. In Ferry county a long narrow belt of granite is found on the summit of the divide between the streams flowing east into the Kettle and Columbia rivers, and those flowing west into Curlew creek and the San Poil river. A similar belt running north and south is crossed on the road from Republic to Wauconda.

Mount Bonaparte, in Okanogan county, stands at the center of a large granite area. It is probable that this area continues southward along the summit between the streams flowing east-

ward into the San Poil river and those flowing westward to join the Okanogan. There is a granite area of unknown width, extending southward from Loomis by way of Conconully and Ruby to the Columbia river. The central portion of this area extends in an east and west direction virtually from the Okanogan river to the Methow, making it one of the largest granite areas of the state. Near Ruby and elsewhere the granite contains a pinkish feldspar, which gives it a beautiful appearance. Granite occurs for two miles east and about eight miles west of Twisp pass, and it is not improbable that this granite continues northwest and southeast forming the divide between the drainage of the Methow and Lake Chelan. Granite occurs along the whole course of Railroad creek, which heads on the summit of the Cascades and which empties into Lake Chelan near its northern end.

Russell* gives several localities in the Cascades where granite and related rocks occur. There is a very large area of granite around Mount Stewart, known as the Mount Stewart granite. All of the high peaks of the Wenatche mountains are composed of this rock, and an area of granite extends from a point about five miles northwest of Blewett to beyond the summit of the Cascades at the point crossed by the Great Northern Railway. Ingall creek, for its whole length to within four miles of its junction with the Peshastin, forms a border of this area. Here the boundary turns and runs nearly due north to seven or eight miles beyond Leavenworth, where it again turns and goes toward the west.

The drainage basin of the north fork of White creek is nearly all in granite, and this area probably connects with that of Cascade pass. Similar granite is found along Indian creek and on Glacier peak. Between the two latter localities a part of the granite branches off from the main mass and in the form of dikes is intruded into the schists to the south. Granite has also been noted along the Sauk river, where schistose rocks are the prevailing type. Another granite area, noted by both Willis† and Russell‡, occurs along the Skagit river from Marblemount to Thunder creek.

*Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, pp. 105-108, 1900.

†Willis: 10th Census U. S., Vol. XV, p. 761, 1886.

‡Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, p. 107, 1900.

Little is known of the granite in the southern part of the Cascades. According to Smith*, granite forms an elevated platform on which stands the volcanic cone of Mount Rainier. Granite has been observed by the writer at the foot of Silver Star mountain, fifteen miles northeast of Washougal on the Columbia river. It is very probable that granite occurs at intervals along the axis of the Cascade mountains from the British Columbia line to a point within a few miles of the Columbia river. Mr. Charles A. Ruddy has informed the writer that a few miles from the mouth of the Dosewallips river on Hood's Canal large boulders of granite are found, which have beyond any doubt been brought from the Olympic mountains adjoining.

Basalt.

The most important volcanic rock of the state is represented by the series of basaltic outflows known as the Columbia lava.† The Columbia lava not only extends over a good portion of Washington, but covers all of Southern Idaho, Eastern Oregon, and extends into California as well. It is doubtless the largest lava flow in the world, covering nearly 250,000 square miles and displaying a thickness in some places in excess of 4,000 feet. Along the margin of the basaltic flow the lava becomes comparatively thin, as is shown near the big bend of the Columbia river, where the granite beneath the lava shows in canyons at depths of 300 or 400 feet. It is generally conceded that the basalt came to the surface through great fissures of considerable linear extent rather than through the usual volcanic vents. In other words the basalt is of a composition which is characterized by a low melting point, and consequently the molten lava would flow for long distances before cooling. Throughout the Columbia lava plain there are no indications of true volcanoes, as far as observed.

The floor upon which the Columbia lava was outpoured was quite uneven. It was a floor composed as far as known of granite, schist, gneiss, and other metamorphic rocks not dissimilar in character, perhaps, from the Okanogan highlands which lie

*Smith: 18th Ann. Rep. U. S. Geol. Survey, Part II, p. 428, 1898.

†This formation is discussed in the papers by Russell, Smith, LeConte, Gibbs, Richthofen, and Symons, which are mentioned in the Bibliography of Washington Geology at the close of this volume.

Photograph by Dr. U. M. Lauman.

MOUNT ST. HELENS AND SPIRIT LAKE.

to the north, or the mountains along the Idaho-Washington line. Some of the bolder hills of the former floor were never covered, as in the case of Kamiack and Steptoe Buttes and others. Other hills, although finally covered by lava, are yet known to have reached heights of 2,500 feet above the surrounding valleys. Such instances are to be seen in the canyon of Snake river.

Wherever the rivers, such as the Snake, have cut deeply into the basalt, the individual lava flows may be readily made out. The number of lava flows presumably varies in different parts of the lava field. According to Russell,* in the canyon of Snake river, where perhaps there is the greatest exposure of lava, eight distinct lava sheets may be seen. Smith † says that ten or more separate flows can be counted in the canyon of Yakima river, and that individual flows may be traced for great distances. The surface of the basalt in some places is yet characterized by the ropy appearance which is always observed upon recent unweathered lava flows. In appearance the basalt is usually black in color, but various tints of brown, red, gray, and green may easily be found. It is observed that the lava varies somewhat in character in the successive flows, and that from the surface of a flow toward the center some differences may be noted. In some of the flows the basalt is very compact and heavy, while in other cases it presents rough and scoriaceous surfaces, caused by the small cellular cavities which were produced by the steam when the rock was molten. In some instances where the molten rock cooled with great rapidity the minerals did not have time to form and the basalt is therefore glassy, but in the central part of the thicker flows where cooling took place with great slowness the rock is crystalline in structure and the crystals can readily be seen by the naked eye. The composition of the basalt from a mineralogical standpoint is that of plagioclase feldspar, augite, olivine, and magnetite, in a glassy ground mass composed of silicates of alumina, magnesia, soda, potash, lime, iron, etc. According to Russell, "chemical analyses of basalt show that in general it contains from 46 to 47 per cent. of silica and from 11 to 22 per cent. of alumina, together with lime, magnesia, potash, etc., in proportions varying from a small fraction of one per cent. to over ten per cent. It is the presence of

* Russell: Water Supply and Irrigation Papers, U. S. Geol. Survey, No. 4, p. 48. 1898.

† Smith: Water Supply and Irrigation Papers, U. S. Geol. Survey, No. 55, p. 15. 1901.

The best known serpentine area in the state is that which encircles the Mt. Stuart granite and which has been described by Russell*. Here the serpentine occurs at many places, notably on the headwaters of the south fork of Icicle creek, on Fortune creek, middle and north forks of the Teanaway river, south of Ingall creek, throughout the drainage basin of Nigger creek, on the ridges to the east of Fish lake and the upper waters of the Clealum river, and in the region around Blewett. In all of these cases the serpentine seems to have been derived from peridotite, and the degree of alteration varies in different portions of the field. Mineral veins are a common accompaniment of the serpentine, and in the region about Blewett, Fish lake, and other localities within the serpentine belt, valuable ores of copper, silver, and gold are found.

In Stevens county several areas of serpentine have been discovered, the best known probably being the one at Valley, on the Spokane Falls and Northern Railway. The serpentine here is a valuable ornamental stone, and the quarrying of it has become an important industry. It has a pleasing color, may be obtained in large masses, and possesses other desirable qualities.

SEDIMENTARY ROCKS.

Sedimentary or stratified rocks are those which are made from the sediments or fragments derived from older rocks. These fragments may be produced along the sea shore by the work of the waves, or they may be produced upon the land by the forces of air and water. Sediments are transported usually by water and deposited upon the ocean floor, in estuaries, or in lakes. Thus we have rocks of marine, brackish water, and fresh water origin. Rocks are also divided according to composition or the kind of sediment which has entered into them, so that we have limestones, clay rocks, sandstones, etc. Another classification that may be made of sedimentary rocks is one according to the geological age in which they were made.

The sedimentary rocks of Washington cover a large portion of the state and are of great importance. At the present stage of knowledge concerning Washington geology the sedimentary rocks are better known than are the other divisions. From their irregular line of contact with the metamorphic and volcanic

*Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, page 109, *et seq.*, 1900.

LAKE OF THE MOUNTAINS, NEAR CASCADE PASS, CASCADE MOUNTAINS.

LAKE OF THE MOUNTAINS, NEAR CASCADE PASS, CASCADE MOUNTAINS.

rocks on the western flank of the Cascades, the sedimentary rocks extend continuously to the coast with the exception of the higher central portion of the Olympics. In the northern Cascades and over the Okanogan highlands, sedimentary formations occur at many places, usually in comparatively small isolated areas. They represent of course the remnants of previous areas of larger size which in the course of time have been greatly reduced by erosion. Many of the areas now separated were at one time connected. These isolated areas are often found where least expected, and so small are they that a great amount of detailed work will be necessary before they are all made known. On the eastern slope of the Cascades in the central part of the range there are some fields of sedimentary rocks of considerable extent. Some outlying areas, disconnected by erosion, reach down to the Columbia river and a little way beyond. The only part of Washington which seems to be quite free from sedimentary rocks is that part of the state which lies to the eastward of the Columbia river and to the southward of the Columbia and Spokane rivers. In the following discussion the different formations will be taken up in the order of their supposed geological position, or geological age, beginning with the oldest.

PRE-CRETACEOUS PERIOD.

A limestone which bears fossils that are supposed to be the remains of crinoid stems lies beneath the iron-bearing schists along Skagit river. Upon evidence offered by these fossils, Willis* ventures the opinion that the limestones are of Carboniferous age. If so, they are the oldest rocks so far identified in the state. In this same article Willis mentions black slates, conglomerates, and limestones from the Monte Cristo district which he thinks may be of Mesozoic age.

Russell† describes a series of sandstones, shales and conglomerates, of a distinct reddish-brown color which outcrop in the mountains bordering Methow river near the old mining camp of Ventura. He calls the series the Ventura formation, and suggests that it may be of Pre-Cretaceous age. He bases his correlation on the stratigraphic relationship of this formation with the two Cretaceous formations that adjoin it—the Similkameen

*Willis: 17th Ann. Rep. U. S. Geol. Survey, Part I, p. 55, 1896.

† Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, p. 198, 1900.

ness. The geological characteristics of each Eocene area is described in more detail in the article on the coal fields of Washington, which is a part of this volume.

During the field season of 1901 the writer collected from a few new localities some plant remains which were submitted for examination to Professor F. H. Knowlton of the United States Geological Survey, and his report is here given:

PRELIMINARY REPORT ON FOSSIL PLANTS FROM THE STATE OF WASHINGTON, COLLECTED BY HENRY LANDES, 1901.

BY F. H. KNOWLTON.

This material consists of seven small lots of specimens, from as many separate localities, all, with a single exception, being in the northwestern part of the state. The species afforded by the various localities are as follows:

Day creek, near Hamilton, Skagit county, Wash.:

Quercus banksiæfolia Newberry.
Quercus sp.

Coal creek, near Hamilton, Skagit county, Wash.:

Quercus banksiæfolia Newberry.
Quercus coriacea Newberry.
Thuja interrupta Newberry.
Glyptostrobus Europæus (Brongn.) Heer.

Cokedale, Skagit county, Wash.:

Quercus banksiæfolia Newberry.
Nyssa ? cuneata ? Newberry.
Cinnamomum n. sp.?

These three localities, being evidently of the same horizon, are best considered together. The most abundant and unmistakable species is *Quercus banksiæfolia* of Newberry. It occurs at all the localities and is a very beautiful species. It was originally described by Newberry,* from Chuckanut, near Bellingham bay, and so far as I now know has been found but once since, namely, by myself at the coal mines at Blue Canyon on the east side of Lake Whatcom. The history of *Quercus coriacea* and *Nyssa ? cuneata* is the same, and the conifer identified as *Glyptostrobus Europæus* was found at the same place.

Thuja interrupta was described originally from the Fort Union group near old Fort Union, North Dakota. I found it also on Blue Canyon, and it is present in the material from Coal creek.

The locality at Chuckanut was referred by Newberry to the Cretaceous, and this was nearly fifty years ago when much less was known of the geology of this region than now, and I do not think it should be so

*Bost. Jour. Nat. Hist., Vol. VII, p. 522, 1863; Extinct Floras of North America, p. 69, pl. xviii, figs. 2-5, 1898.

regarded. From the general appearance of the plants alone I should incline to place the age as somewhere near the Middle Tertiary, certainly younger than beds at Carbonado, etc. In any case these three localities represent an age similar to that of the beds at Blue Canyon.

Coal Creek, near Keese, Whatcom county, Wash,:

Sequoia Langsdorfii (Brongn.) Heer.
Sabal similar to *Sabal* n. sp., from Liberty, Wash.
Cinnamomum n. sp. of vein XII, Franklin, Wash.
Cinnamomum sp.
Pipu n. sp.
Phyllites n. sp. of vein XII, Franklin, Wash.
Populus n. sp. of vein XII, Franklin, Wash.

This collection contains beautifully preserved and very interesting material, some of which is undoubtedly new, and much of which is identical with, or similar to, forms from vein XII at Franklin, Wash. On this ground I should regard the age as similar to that at Franklin. I have not given the names of the new species in advance of their publication in my proposed monograph.

Skykomish, Snohomish county, Wash.:

Anemia n. sp., as found at Carbonado.
Glyptostrobus sp., as found at Roslyn.
Ficus n. sp., as found at Carbonado.
Ficus n. sp., as found at Liberty.
Celastrus n. sp., as found at Carbonado.

The age of this locality would seem to be the same as that at Carbonado and Roslyn, the beds at Liberty being a little lower. In any case it is probably not greatly different from the age at Carbonado.

Black River Junction, King county, Wash.:

Acer n. sp.
Cinnamomum n. sp.
Ficus ? n. sp.

This material is the same as that obtained at Steel's Crossing and, judging from the matrix as well as the plant impressions, came from the identical beds. There is no evidence tending to change my opinions on the age.

Republic, Ferry county, Wash.:

Thuja interrupta Newberry.
Sequoia Langsdorfii ? (Brongn.) Heer.
Cinnamomum sp.

There is too little of this material to base a very definite conclusion on, but it would seem to be similar or identical with the beds in Skagit county.

Miocene Epoch.

Marine Miocene strata which have been correlated with the Astoria beds, outcrop along the shore from Port Blakely to

Pleasant Beach, on Puget Sound. The formation at this locality consists of several thousand feet of sandstone, shale, and conglomerate, all tilted at a high angle. Dall* mentions rocks of this age as occurring at Shoalwater Bay (Willapa Harbor), Bruceport, and Bellingham Bay. Willis† mentions a fresh water formation in the southeastern portion of the New Castle hills which he correlates with the Miocene.

The Ellensburg sandstone, as described by Russell‡, is the largest fresh water deposit of known Miocene age yet discovered in Washington. The formation is well exposed along the Yakima river between Dudley and Ellensburg, and consists of strata of sandstone, volcanic dust, and conglomerates, both consolidated and unconsolidated. This formation lies immediately above the Columbia basalt, and reaches a thickness of about 1,500 feet in the North Yakima area.§ The Ellensburg formation was deposited in a large lake which covered much of central Washington, the exact boundaries of the lake being as yet unknown. The lacustrine sediments, being as a rule quite incoherent, have been largely removed by erosion.

Pliocene Epoch.

It is not improbable that future study will disclose rocks of this age among the sedimentary formations which make up the southwestern part of the state. Dall‖ mentions the occurrence of a "mytilus bed" at Bruceport which he thinks is of Pliocene age.

QUATERNARY PERIOD.

Pleistocene Epoch.

Marine Pleistocene deposits within the state are confined chiefly to raised beaches. Dall¶ writes of the occurrence of beds 30 to 40 feet thick which lie uncomformably upon the Pliocene at Bruceport. Raised beaches of Pleistocene age occur at Alki and Restoration Points and elsewhere about Puget Sound wherever the beach is made up of bed rock. Pleistocene sediments in the nature of glacial deposits occupy a large portion of

* Dall: Bull. 84 U. S. Geol. Survey, p. 228, 1892.

† Willis: 18th Ann. Rep. U. S. Geol. Survey, Part III, p. 414, 1898.

‡ Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, p. 127, 1900.

§ Smith: Water Supply and Irrigation Papers, No. 55, p. 17, U. S. Geol. Survey, 1901.

‖ Dall: Bull. 84, U. S. Geol. Survey, p. 228, 1892.

¶ Dall: Bull. 84, U. S. Geol. Survey, p. 227, 1892.

the state. In all of the mountain districts, except in the Blue mountains, glaciers once covered the mountain tops and filled the valleys, and the latter are now partially occupied by terraces, boulders, and moraines. The region about Puget Sound was occupied by great ice masses which came from British Columbia, the Cascades, and the Olympics. The sediments left by these glaciers consist of till, with stratified sand, clay, and gravel, in all averaging in thickness not less than five hundred feet.

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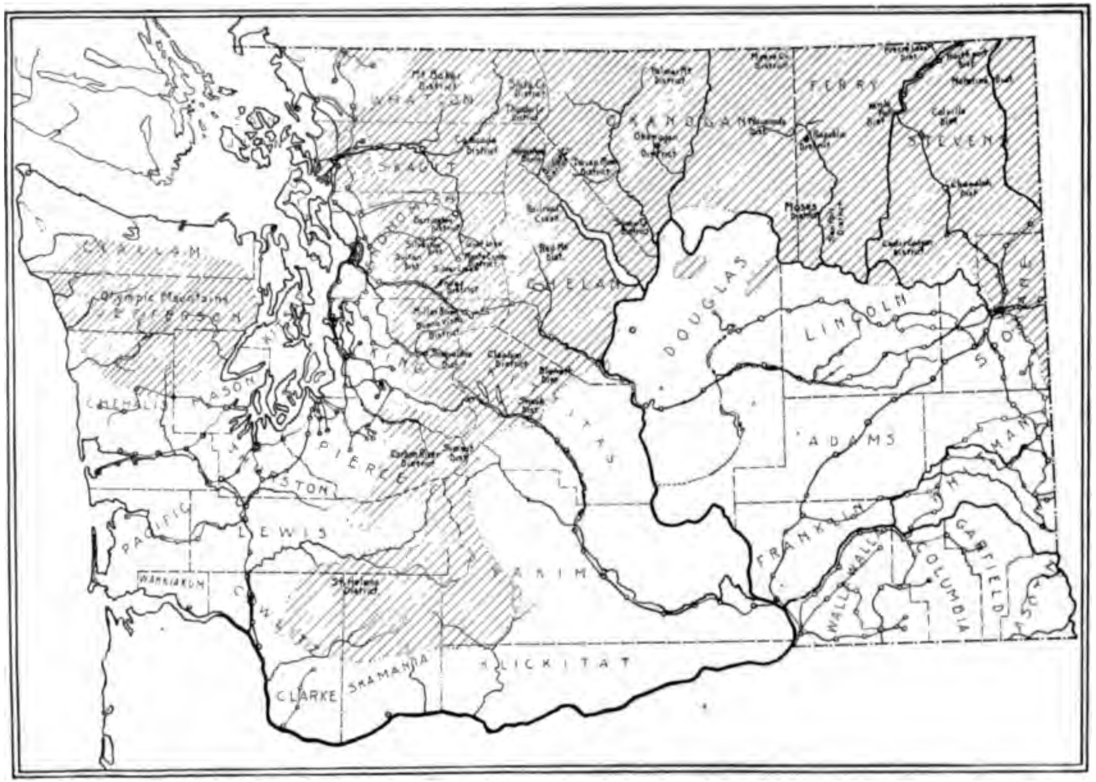
PREFACE.

In this article on the METALLIFEROUS RESOURCES OF WASHINGTON only an outline or sketch of the subject is attempted, preparatory to detailed descriptions of the various mining districts that will be given in later reports. Some of the representative or typical metalliferous deposits are described, selected here and there from the large area in which the metallic minerals are known to occur. No attempt is made to classify the ore deposits according to their mineral contents, but the usual products such as gold, silver, copper, lead, etc., are all described together. This is done because of the peculiar intimate association of these minerals, one with another, in the veins of ore.

The geographical classification of the metalliferous deposits is that by counties, districts and mines. The district boundaries as given in this report are largely those of convenience, and they may vary considerably from those established by law or custom. The proper outlines of the districts will be given when these are later described in detail. In this article the name of the writer of each section is placed at the beginning of it, except that the State Geologist has been responsible for the preparation of the article as a whole, and all unsigned sections have been written by him. The names of the persons who have given the information contained in the minor parts are placed in brackets at the end of the paragraph.



A map indicating the locations of the principal mining districts, and the approximate boundaries of the region in which metalliferous deposits occur.

THE METALLIFEROUS RESOURCES OF WASHINGTON.

INTRODUCTION.

In at least thirteen of the counties of Washington metalliferous deposits are known to occur, and in all of these counties from one to several mining districts have been organized. The metallic minerals are practically limited to that area on the geological map which is designated as the region of metamorphic and igneous rocks of unknown age. Veins of ore therefore occur at many points throughout northern Washington from the neighborhood of Mount Baker eastward to the Idaho line, and from the international boundary southward along the length of the Cascades to within a few miles of the Columbia river. The Olympic mountains presumably contain rocks analagous to those of the Cascades, but it has not yet been demonstrated that valuable metalliferous deposits occur within the Olympics.

In this brief description of the metalliferous resources of the state it is not feasible to separate the metallic minerals one from another and give an account of the occurrences of each. In most cases these minerals occur together, oftentimes in the same vein, and generally in the same district. Of the various classes of ores the sulphide ores are by far the greatest in abundance. Along with the sulphides, arsenides and antimonides are very common. Oxides and carbonates do not commonly occur, and native minerals are conspicuously rare.

Gold is found in all of the mining districts, and even in all veins. It occurs most frequently associated with iron pyrite, arsenopyrite, chalcopyrite, sphalerite and galena. In a few districts, as Mount Baker and Squaw creek, gold occurs with tellurium as a telluride. It does not commonly occur in quartz in a free-milling condition, at least very far below the surface.

Many stamp mills have been erected which treated gold-bearing quartz successfully when the ore was taken from the surface, but this process had to be abandoned when depth was attained where the ore became base. Comparatively little gold is obtained in the state from placer diggings. Placer deposits do not seem to have been formed to any large extent, presumably because of an absence of quartz ledges which carry free gold.

Silver is as widespread in its occurrence as gold, and practically none of the ledges are free from it. It occurs most commonly as a sulphide, in close association with other sulphide minerals, notably galena. In some of the districts silver-lead ore is the chief product. In other districts, as Cedar canyon, silver is practically the entire product, occurring in the native form as well as a sulphide. In other instances, as about Republic, silver occurs in small quantities, especially in comparison with the gold values.

The copper minerals are widespread in occurrence, there being very few metalliferous deposits of any kind which do not contain some copper. It is not uncommon to find gold, silver and copper in about equal amounts as regards value. In some districts, as that of Republic, copper minerals, if present at all, occur in exceedingly small quantities. On the other hand there are some districts, as Index and Carbon river, where practically all of the values in the ledges come from the copper minerals alone The most abundant copper mineral is chalcopyrite, with bornite as a natural though minor associate. Tetrahedrite or gray copper is not uncommon, and chalcocite is found in some veins. Native copper has been found at several places, as at Eatonville and on the Quilcene river near its mouth, but it is comparatively rare. The oxides and carbonates scarcely occur at all west of the summit of the Cascades; they occur in small quantities at many places in eastern Washington where weathering has not been followed so closely by erosion, as in the humid region nearer the coast.

About the only lead mineral found is galena, which occurs abundantly in association with the other sulphides. While it is very rare at times, it is yet a common mineral in a large majority of the mining districts of the state. In some districts, as Colville, Horseshoe basin and others, galena constitutes the chief metallic mineral of the ore veins.

Zinc, in the form of sphalerite, or zinc blende, is also of widespread occurrence, although the amount found in any one vein is never large. It occurs in intimate association with the other sulphides, especially with galena.

Arsenic occurs very commonly in the ore veins, usually in the form of arsenopyrite. This mineral is always gold-bearing and for that reason its presence is looked upon as desirable. In some cases, as in the Monte Cristo mine, arsenopyrite occurs in such large quantities that the arsenic constitutes an important commercial product. Native arsenic, realgar and orpiment also occur, notably about Monte Cristo and Goat lake.

Antimony, sometimes in the metallic form, sometimes as stibnite or tetrahedrate, occurs in more or less abundance in many districts. In a few instances, as at the Happy Thought mine, on Miller river, King county, the quantity is sufficient to make it of commercial importance.

Molybdenum, in the form of the sulphide, molybdenite, frequently occurs in the ore veins, generally in very small quantities. In the Crown Point ledge, on Railroad creek, it occurs in sufficient amount to make it worth the while to work the mine for this one product alone.

The total value of the metalliferous products of Washington for the past twenty years, as given by the Director of the Mint, has been about $10,000,000. The output of 1901 is estimated at $1,072,680. The metalliferous deposits of the state, because of their isolation and generally refractory character of the ores, are necessarily of slow development. With the building of railways into the mining districts, and with improved facilities for ore treatment, a great development of the mining industry in Washington is sure to follow.

In the following description of the metalliferous deposits of the state a classification is made according to counties, districts, and mines. A beginning is made on the eastern border of the state, and the counties are then taken in turn to the westward and southward. The mining districts are not all represented by any means, only representative ones being described. Similarly in each district considered only a few of the mining properties, as a rule, are mentioned. Those selected are so chosen because they are typical of the district, or because being more accessible they could be more readily visited in the hasty field work. The

properties herein described therefore represent but a fraction of the very large number found throughout the mining regions of the state.

STEVENS COUNTY.

Stevens county lies in the extreme northeastern corner of Washington, extending in an east and west direction from Idaho to the Columbia and Kettle rivers, and from Spokane and Lincoln counties on the south to the state boundary on the north.

In its topography, Stevens county is characterized by three prominent ridges, and three prominent valleys, all having a north and south course. Near the Washington-Idaho line a mountain ridge having a general height of about 5,000 feet, extends from the Pend d'Oreille river at Newport to British Columbia. Parallel to this chain a second one lies between the Pend d'Oreille river on one side, and the Colville on the other, and has an altitude of about 4,500 feet. To the westward, situated between the Colville and Columbia rivers, is the third chain, somewhat lower than the others, its highest point extending to about 4,000 feet above the sea. The larger streams have completely severed the ridges in several instances, and the smaller streams have produced many prominent passes and gaps. Of the conspicuous north and south valleys of the county, the Pend d'Oreille is comparatively narrow, and has the canyon aspect strongly developed. On the other hand the Colville is quite a broad valley in which the river lazily meanders across its long flood-plain. The valley farthest westward, that of the Columbia, is also broad, and has an elevation above the sea of about 1,100 feet at the point where it enters the county.

Stevens county, although lying in the great basin between the Cascades and the Rockies, is well watered, its elevation being such that the precipitation in the form of snow and rain amounts to over 25 inches per year. The rivers are large and give to the county an abundant water supply, while their falls and rapids will some day yield great power as well. The Columbia in Stevens county is a broad and deep stream, and yet is not navigable

because of its strong current and the rapids along its course. Clark's fork, or the Pend d'Oreille, is one of the largest tributaries of the Columbia, and is navigable for a part of its course in Stevens county. The Colville is a small river, draining a broad fertile valley, which was settled early in the history of Washington. The Spokane forms a part of the southern boundary, and the Kettle a part of the northwestern boundary. The more elevated parts of the county are covered with a strong forest growth of evergreens. The mountains along the eastern boundary are included within the Priest River Forest Reserve. Practically the entire county is forested, although when the lower valley levels are reached the timber becomes somewhat sparse.

Stevens county is largely a region of metamorphic and igneous rocks. The basalt of the Columbia plain reaches the Spokane river at the southern limits of the county. The north and south divides are composed mainly of granite, with gneiss, schist, crystalline limestone, and other metamorphic rocks. The crystalline limestone yields an excellent marble at several places, and it often has serpentine as an associate. At a few localities veins of coal are found, which are doubtless analagous in age and mode of origin to the Tertiary coals of the western part of the state. Metalliferous deposits have been found in many parts of Stevens county or wherever careful prospecting has been carried on. The ores occur for the most part in the higher hills which constitute the divides between the larger streams. Silver has been the most prominent metal mined, occurring in the forms of silver sulphides, native silver, and silver-lead. In some ledges gold is the most important metal, and in a number of others, copper in various mineral forms is the chief constituent.

NORTHPORT DISTRICT.

Bullion.—On Bullion mountain, near the Columbia river, there is a group of seven claims belonging to the Bullion Mining Company, of Spokane. The property is about eight miles west of Northport and three and one-half miles from the Spokane Falls & Northern Railway. There are two ledges on the property, one eighty feet and the other fifty feet in width. They both strike northeast and southwest, and dip to the northwest. On ledge No. 1 a shaft has been sunk a distance of 160 feet. At

the 50 foot level a drift has been run 80 feet, and at the 150 foot level another drift has been run 100 feet. On ledge No. 2 a shaft has been sunk 100 feet, and at the 100-foot level a drift 40 feet long has been driven. A number of open cuts have been made to show the width of the veins. A water-power plant has been installed on Crown creek which generates ample power for running a sawmill, drills, concentrator, etc. The company has already spent $15,000 in developing the property. No ore has yet been shipped, but there is now on the dump 50 tons of shipping ore and 100 tons of concentrating ore, all taken out in development work. The concentrates yield on an average, gold $2, silver 40 ounces, and lead 70 per cent. (H. J. Brown, secretary, Spokane.)

Silver King.—The Silver King Mining Company's property, consisting of four claims, is situated four and one-half miles southeast of Northport. It contains several veins composed largely of silver-lead ore. Some assays of solid ore have yielded silver 6 ounces and lead 77 per cent. Three shafts have been sunk, 30 feet, 28 feet, and 20 feet in depth, respectively, at a total cost of $1,000. (J. R. Fleming, secretary, Spokane.)

MYER'S FALLS DISTRICT.

Mint.—On Gold hill, near Myer's Falls, is located the Mint group of claims. There are three veins, varying in width from eight to twenty-five feet, with a northwest and southeast strike, and a dip to the southwest. A tunnel and shaft aggregating 200 feet have been driven, at a cost of $2,500. Assays on the ore have given gold $8, silver 5 ounces, and copper 8 per cent. (D. F. Strobeck, Spokane.)

St. Paul-Express.—These claims are located very near the Mint group, on Gold hill. Two veins are found here, from 12 to 35 feet wide, striking northwest and southeast and dipping to the southwest. A small amount of development work has been done, consisting chiefly of a tunnel and a shaft. Assays of the ore have been made which give gold $7.50, silver 5 ounces, and copper 9 per cent. (D. F. Strobeck, Spokane.)

FLAT CREEK DISTRICT.

Examiner.—The Examiner Mining Company's group of four claims is situated on Mineral hill in the Flat creek district.

Work was begun by the present company in January, 1899, and since then they have driven 450 feet of tunnels and shafts. Steam power is used for hoisting and pumping. The work done represents an expenditure of over $10,000. The vein is six feet wide and strikes northeast and southwest. The dip is to the northwest. Assays on the ore vary from $2 to $16 per ton in gold and silver. (W. Genge, secretary, Spokane.)

COLVILLE DISTRICT.

Bonanza.—The Bonanza mine is located four miles northeast of Bossburg. The property was originally located in 1885, and came into the hands of the present owners, the Deer Trail Consolidated Mining Company, in January, 1900. The vein has a width of about eleven feet. Since the present company obtained control of the property it has shipped about 1,500 tons of ore of an average value of $16 per ton, chiefly in lead and silver. The company has erected a shaft house, an ore house, bunk houses and boarding houses, and a blacksmith shop. A steam hoist is also installed. The total length of underground workings including shaft, levels, stopes, etc., amounts to about 2,500 feet. The total cost of all development work amounts to about $30,000. (W. W. Tolman, Spokane.)

CHEWELAH DISTRICT.

Minnehaha.—This property is located on the east fork of Chewelah creek, in section 36, T. 33, N. R. 40 E. The ledge varies in width from 8 to 30 feet, and strikes northwest and southeast, with a southwesterly dip. The average assay value is $7.50 in gold, 6.5 ounces in silver, and 6 per cent. copper. A tunnel 40 feet long has been driven, costing $500. (D. F. Strobeck, Spokane.)

Blue Creek.—The Blue Creek Copper Mining Company, of Spokane, has a group of three claims about a mile and a half from the Blue creek switch of the Spokane Falls & Northern Railway. The three claims join each other end to end, all being on the same ledge. The ledge averages about six feet wide and strikes northwest and southeast. Assays of $26.75 per ton in copper have been obtained. About 300 feet of underground development work has been done, at a cost of $3,000. (J. J. Brown, Spokane.)

SPRINGDALE DISTRICT.

Kemp-Komar.—The Kemp-Komar Copper Mining Company has two claims which are located about six miles north of Loon lake. There is one vein 12 feet wide which carries a paystreak varying in width from a few inches to 5 feet. It strikes northeast and southwest and dips about seventy degrees to the northwest. Four car loads of ore have been shipped which averaged 25.5 per cent. copper, while another car load gave 16 per cent. copper. The total values are in copper. A shaft has been sunk 200 feet and from the bottom a drift has been run 250 feet. In another part of the vein a shaft has been sunk a distance of 40 feet. One tunnel 60 feet long, another 90 feet, and a drift 20 feet long have also been driven to develop the ore body. Near the surface the ores are carbonates and oxides, except in the west workings, at the bottom of which the sulphides replace the surface ores. Occasional assays show a small value in gold and silver, the highest in gold being $2 per ton, and in silver 6 ounces per ton. (L. K. Armstrong, Spokane.)

Honest John.—The Honest John Mining Company's group of three claims is located about two miles northwest of Springdale, on the Spokane Falls & Northern Railway. The vein is five and a half feet wide and dips to the southeast, with a northeast and southwest strike. The values are mainly in silver and lead, and assay returns of $40 per ton have been received. In the development of the property a tunnel 120 feet in length has been driven, several small shafts have been sunk, and some open cuts made. (W. O. Applequist, secretary, Spokane.)

CEDAR CANYON DISTRICT.

By Wm. S. Thyng.

Cedar canyon district is located in the southwestern part of Stevens county, in an air line twenty miles west of Springdale, on the Spokane Falls and Northern Railroad, and thirty-five miles north of Davenport, on the Washington Central branch of the Northern Pacific. The district is reached from both of these places by wagon roads, the length of the road from Springdale being twenty-five miles, and of that from Davenport forty-two miles. While this district is perhaps not as well known as some in the state, it has nevertheless within the last few years produced a large amount of ore. The ore, until late

in the summer of 1901, was all shipped by way of Davenport, but since the shortening and improving of the road to Springdale, accomplished during the past season, probably most of the ore mined will be shipped from that point until the time comes when the district itself will be reached by a railroad. Throughout the district the ore is mined wholly for its silver contents, although in many cases lead is also saved in the smelting.

Deer Trail.— The Deer Trail properties, owned and operated by the Deer Trail Consolidated Mining Company, are and have been by far the largest producers and shippers of ore in the district. The president of the company is Mr. J. D. Chaplin, address, St. Catherine, Canada; Senator W. W. Tollman, Spokane, Washington, is vice-president and general manager. The headquarters of the operating department is in Spokane. The company owns the following claims in the district: Deer Trail, Deer Trail No. 2, Legal Tender, Victor Fraction, Elephant, and Baby Elephant.

There is but one ledge, which has an average width of four feet, a strike of south thirty degrees west, and an average dip of forty degrees to the southeast. This dip is found to be quite variable, ranging from ten to forty-five degrees. The country rock or formation is a stratified limestone, which runs northeast and dips between eighty and eighty-five degrees to the northwest. The vein matter is made up of quartz containing inclusions of country rock in places. The ore in the upper levels consists of highly oxidized sulphurets and chlorides, but it passes, however, in depth, to sulphides both of lead and silver. Galena, when found, generally averages between 10 and 15 per cent.; the silver found with the galena running from 50 to 500 ounces per ton of ore; gold, both in the upper and lower levels, is generally found to the amount of $1 to $2 per ton of ore; sphalerite (zinc blende) is always found accompanying the galena, and in amounts of about 8 per cent. to each 15 per cent. of the galena. A pay streak of ore, from three inches to four feet in width, with an average of twelve inches, is found, while in places the entire vein widens to 12 or 15 feet. The pay streak is generally very continuous and shows a good parting of gouge, which is almost pure talc. The average value of all ore taken out of the mine is about 100 ounces in silver per ton. The ore is hand picked on the surface, and part of it spalled; the average

value of all ore shipped is 200 ounces in silver and eight per cent. in lead. The mine was opened in 1895, and was acquired by the present company on the 25th day of January, 1900. The vein lies nearly parallel with the surface of the mountain and is reached at a number of points by short tunnels.

The total extent of underground development is about 2,000 feet, but the area of stoped ground could not be ascertained. The ore is mined entirely by hand, the universal method throughout the district. About $30,000 has been expended in development and in surface work and improvements, and the estimated value of the output to date is approximately $500,000; the exact amount of ore mined and sold to date could not be ascertained. The statistics of yield and value are from Senator W. W. Tolman, general manager of the mine.

Silver Queen.—This mine is owned and operated by the Silver Basin Mining Company, of which the president is Mr. W. O. Van Horn, and the general manager is Mr. L. E. Van Horn, both of Fruitland, Washington. This property lies about three-quarters of a mile southwest of the Deer Trail. The ledge strikes along the magnetic north and south line, with a dip that is usually about vertical, the deflection occasionally being to the east or to the west. The west wall is remarkably well defined. The ledge is in a contact between white and blue limestone, the white limestone lying to the east, where the parting between it and the country rock is not easily distinguished. The average width of the ledge is about six feet. The value of the ore is wholly in silver, which occurs largely as brittle silver, although recent developments during the past winter, have uncovered a considerable amount of native silver along parting planes. The lead contents of the vein are very low, but where galena is found, it generally runs high in silver, often containing from 500 to 600 ounces to the ton. The pay streak varies greatly in thickness, but appears to follow most closely the west wall. The gangue matter is chiefly dolomite.

Silver Seal Fraction.—Immediately south of the Silver Queen and located upon the same ledge, is the Silver Seal Fraction Mine, represented by Mr. F. M. Van Horn, of Fruitland, Washington. Upon this properry an adit tunnel 341 feet long has been run, cutting the ledge at a depth of about 80 feet. This

tunnel was driven and is controlled jointly by the Silver Queen and the Silver Seal companies. From this tunnel 204 feet of drift has been driven in the Silver Seal, and from this drift considerable stoping has been done, at one place to a height of 24 feet. From the point where this drift crosses the property line, or end line of the Silver Queen, it has been continued for 110 feet. Upon the Silver Seal property a shaft has been sunk 76 feet from the surface, which intersects the drift about 20 feet south of the tunnel head. This shaft is entirely in ore. Upon the Silver Queen a shaft has been sunk, which in September, 1901, was some 215 feet in depth. Since that time this shaft has been continued and connection has also been made with the Silver Seal drift. The plan of both companies is to work in the future, each from its own shaft, the Silver Queen being already equipped with a hoisting plant. The Silver Seal has shipped eleven carloads (about 220 tons) to the Northport Smelter, via Davenport, and in September, 1901, had about 700 tons of shipping ore upon the dump. The Silver Queen has shipped three carloads of ore and has at present something over 50 tons upon the dump.

Brooks.—This is another property of considerable importance in the district, and is owned by the Brooks Mining Company, of which the president is Mr. E. L. Spencer, of Davenport, Washington. This company owns three claims in the district, the Brooks, Success, and First Adventure, but at the present time is operating only the Brooks claim, which is located immediately north of the Silver Queen and is supposed to be upon the same ledge. The development to date consists of a shaft 75 feet in depth, from which 50 feet of drifting has been done, and a tunnel 265 feet in length, completed last season, and which taps the ledge at 90 feet depth. This tunnel is driven through a saccharoidal limestone. The ore is similar to that of the Silver Queen. Two car loads of the value of $3,000 have been shipped from the drift workings.

Orchid.—Four claims, the Orchid, Laura E., Cyclone, and Cornell are owned by the Orchid Mining Company, of which the president is Mr. G. W. Kipp, address, Cortez, Pennsylvania, and the general manager, Mr. C. L. Young, of Davenport, Washington. This property is located about three-quarters of a mile

almost due south of the Deer Trail. The claims cover two ledges, which have a north and south strike. The development work, consisting of tunneling, drifting, and a short shaft, aggregates 1,750 feet. Some little stoping has also been done. The company shipped three tons of high grade ore in August, 1900, to the Tacoma smelter. The ore as found so far consists of chlorides of silver and lead, in intimate association, with small amounts of brittle silver.

While the properties above mentioned are probably at the present time the largest and most important of the district, there are others upon which considerable development work has been done and which would seem well worthy of mention. These include the Silver Basin, Moonshine, Jolly Boy, Emerald, Hoodoo, Hoodoo Extension, Saturday Night, Sunday Morning, Plata Rica, and others.

The district is highly mineralized and many of the ledges yield exceptionally good values in silver. As is the case with so many of the mining districts in this state, the vexed question is that of transportation. With a railroad directly into the district a number of properties, now standing idle on account of lack of shipping facilities, would at once be placed upon a firm paying basis.

FERRY COUNTY.

Ferry county lies between the counties of Stevens on the east and Okanogan on the west, and embraces a part of the large tract that has been commonly known for so many years as the "Reservation." Until the present time Ferry county has suffered because of its isolation, but accessibility to it will be largely increased by the two railways which are now being constructed into the heart of the county, the local terminal point of each being Republic.

In its topography Ferry county is interesting although simple. The county has on its southern border the winding valley of the Columbia, and on its eastern border the valleys of the Columbia

and the Kettle. A broad continuous valley extends north and south through the central part of the county, made by the San Poil river and Curlew creek, both heading near together in the neighborhood of Republic, but flowing in opposite directions. Between the valley just mentioned and that part of the Columbia-Kettle is a north-south ridge or watershed rising about 4000 feet above the main valleys. To the westward of the San Poil-Curlew valley the surface rises gradually to the western border of the county, and beyond it until the Okanogan divide is attained. On the whole the topography of the county is characterized by broad valleys and rounded hills, rather than by canyons and mountains; it is an old topography rather than a new one. The grades are so moderate that roads are easy of construction in practically all parts of the county. Along the sides of the larger valleys terraces rise one above another, the uppermost one being often 600 feet above the stream below. Across the valleys in occasional instances the moraines inherited from glaciers have formed slight dams, producing small shallow lakes.

Although Ferry county has an average rainfall of but fifteen inches per year, still all the higher parts of the county are covered by a good forest growth. In the northeastern part of the county, on the higher divides adjacent to the Columbia and the Kettle rivers the groves of pine, tamarack, and other evergreens are very fine and assume considerable commercial importance. In the valleys, and on the lower hills, the decreased rainfall does not admit of the growth of trees, but a luxuriant bunch-grass growth is found instead. The drainage of the county is altogether into the Columbia, the two chief tributaries of that stream being the Kettle and the San Poil. The small streams of the county head for the most part among the granite and crystalline rocks, and are conspicuous for their purity and freshness.

As to the geological features of the county it may be noted in a general way that granite, gneiss, schist, and crystalline limestone are the prevailing formations, with some intrusive and extrusive rocks of a late age. A broad belt of granite, flanked by gneiss, schist and crystalline limestone, lies immediately to the westward of the Columbia and Kettle rivers, and extends from the southern to the northern limits of the county. A parallel belt of similar rocks is found along the western side of the county. About Republic there is an area limited to a few square miles

where conglomerates, sandstones, and shales of Eocene age occur. In several parts of the county extensive sheets of lava, chiefly basalt, are found, which are of late origin; in some instances dikes of intrusive matter are prominent, and many of the veins of ore have some connection with these.

At many places in Ferry county metalliferous deposits occur, and there is no part of the county but what could be termed good prospecting ground. Wherever the base ores occur development work has not progressed very rapidly because of the difficulties encountered in removing the ores to points of treatment; on the other hand wherever ledges of quartz are found, especially those which hold out promises of being free-milling, development work has proceeded more rapidly. The large quartz edges about Republic, from which some high assays were had of the surface croppings, have attracted a great deal of attention from the date of their discovery. About Curlew, Empire and Belcher mountain, in the northern part of the county, and in the vicinity of Keller, in the southern portion of the county, a large amount of development work has been done on the ore deposits found thereabouts.

REPUBLIC DISTRICT.

The Republic district is located toward the western side of Ferry county, and a little to the northward of the north-south midway point. The district has an approximate length and width of eight miles each, and lies immediately about the confluence of Granite creek with the San Poil. The town of Republic lies at the center of the district, and is easily reached by good roads from the north, east, south and west. The regular stages connect daily with the Spokane Falls & Northern trains at Myer's Falls, and with the Canadian Pacific trains at Grand Forks, each of these points being approximately 42 miles from Republic. Two railways are now building to Republic, both coming from the northward via the Kettle river and Curlew creek. These roads will be in operation by the spring of 1902.

The region immediately about Republic is one of comparatively low relief, the hills possessing rounded forms and gentle slopes. The soil has accumulated to a considerable thickness, almost completely hiding the bed rock except along the stream courses and on an occasional steep hill slope. Some of the hill

slopes are bare of trees, but the most of them are forest covered. The snowfall is not heavy, so that the precipitation, which amounts to about 15 inches per year, occurs chiefly in the form of rain.

The oldest rock formations represented about Republic are certain schists, gneisses and crystalline limestones, into which large masses of granite have been thrust. After the intrusion of the granite there was a long period of erosion, followed by the formation of lake basins, one of which existed in and about the Republic district. In this lake deposits of clay, sand and conglomerate were made, which in time were hardened into rock. By the fossil leaves found in the sediments the lake beds are known to be of early Tertiary (Eocene) age. After the deposition of a considerable thickness of these sedimentary beds they were greatly disturbed and tilted at various angles by intrusions of porphyritic andesite. Since the dislocation of the stratified rocks they have been largely removed by erosion, but in the town of Republic and at several points to the northward remnants of them may be easily found. The andesite mentioned above is of a dark gray color, somewhat soft, and easily disintegrated. It is the most frequent rock met with immediately about Republic, and the principal quartz ledges are found within it.

The general course of the veins of ore is north and south. Occasionally there is some modification in direction, as along the northern border of the district where the ledges run more to the northeastward and southwestward. As a rule the ledges are unusually wide, with great persistency in length, and as far as the eye can see are composed wholly of quartz, with a very little calcite. The quartz is nearly pure white, with occasionally some very narrow black bands within it. It is very tough, hard to break, and posses a well-marked conchoidal fracture. It appears to be wholly devoid of the sulphide minerals, and even in the richest ore the free gold is rarely or never seen even with a strong magnifier.

Various plans of treating the Republic ores have been tried, but the only very satisfactory results have been those obtained by smelting, and it is not unlikely that this will be the method employed in the future. In the matter of the extraction of gold from the ores of the district it is interesting to note that in a

paper read before the American Institute of Mining Engineers, at Washington, D. C., February, 1900, Messrs. T. M. Chatard and Cabell Whitehead state the results of experiments made in the chemical laboratory upon Republic ores. The object of their investigations was to explain the well known low percentage of gold-extraction by amalgamation. After making numerous tests of the ore, they finally arrived at the following method:

"A sample of the coarse ore was finely pulverized, and the metallic iron present removed by a magnet. Ten grams were then digested on the water-bath for one hour with hydrochloric acid, diluted with an equal bulk of water, and then filtered. The washed residue was then digested with a hot solution of sodium carbonate to extract any silica rendered soluble by the acid treatment, while the acid solution was evaporated to dryness to recover any dissolved silica. The solution was then analyzed by the usual methods, and the complete results were as follows.

Insoluble residue	97.11	Zinc	.025
Soluble silica	.31	Lime	.066
Alumina	.33	Magnesia	trace
Ferric oxide	.40	Sulphur	.060
Ferrous oxide	.29	Phosphoric acid	.018
Copper	.016	Water	1.580
Total			100.155

"This analysis indicates that the material which envelopes the gold and prevents its dissolving in the cyanide consists mainly of hydrated oxides of aluminum and iron, since the amount of 'soluble' silica is insufficient for any known combination with the bases, even if we suppose that all of it was originally so combined. * * *

"As a rule, the gold and silver in these ores are in the form of very minute particles, and these appear to be so enveloped in the slimy hydrates as to be floated off by the water when the ore is panned; the hydrates also forming a coating impervious to cyanide solutions. When the ore is treated with acid the hydrates are dissolved, and the gold, thus set free, is easily collected in the pan. The action of heat by driving off the water of hydrates, leaves the oxides in a brittle and porous condition, so that they either separate from the gold or permit the cyanide solution to reach and dissolve it. Calcium has, however, the reverse effect upon the silver, as the extraction of this metal was always less after the ore had been heated than before, due probably to the conversion of sulphide of silver into metallic silver, which is less easily soluble in cyanide than the sulphide."

Although a large amount of development work has been done upon very many properties in the district, lack of space forbids the description of all but a few of the more prominent mines.

Republic.—This mine, now owned by the Republic Consolidated Gold Mining company, is the best developed property in

the Republic district. It is located at the southern limits of the town of Republic, on the western side of Granite creek.

The ledge outcrops on the summit of a sharp ridge which rises about 700 feet above the bed of the stream. It has a north and south strike, with a dip to the eastward of about 80 degrees. The foot-wall is a porphyritic andesite, while the hanging wall is conglomerate, overlaid by sandstone. At the surface the vein varies in width from four to twenty-four feet.

In the development of the ledge three tunnels were driven from the eastern hill slope through the sandstone and conglomerate until the vein was reached and cross-cut. The lowest or mill tunnel has a length of 2,225 feet, and cuts the ore body 600 feet below its outcrop. This tunnel is on a level with the upper landing floor of the mill, and is the one now used altogether in the working of the mine. From the cross-cuts, or points where the tunnels penetrated the vein of ore, drifts have been made in both directions for considerable distances. From these drifts winzes and raises have been driven until the ore body has been thoroughly prospected. As a result of the underground work it has been found that within the vein there exists a well-defined ore shoot which extends downward from the widest point of outcrop to the lowest point reached, viz., the 600-foot level. This ore shoot is roughly lenticular in form, has a width of fully thirty feet at its center, gradually becoming narrower when followed either way along the strike of the vein. The ore shoot does not stand vertical, but dips to the southward at an angle of about 60 degrees.

The ore varies very greatly in value throughout the ledge. Large bodies of quartz have been found of a value too low to pay the cost of mining and reducing. On the other hand pay streaks of extraordinary richness have been discovered. Barren quartz and rich quartz all look so nearly alike that only by repeated assays can the miner know in what kind of ore he is working. The ore contains about 90 per cent. of silicia, with some alumina, iron oxide and lime. No traces of arsenic, antimony, copper or lead are found. The quartz is as a rule very white, although sometimes it is banded and somewhat resembles onyx or agate.

The best grade of ore which is taken from the mine is mostly shipped to the smelters at Everett and Tacoma. The ores of

lower grade are treated at the mill owned by the Republic Reduction Company, which is located at the mouth of the lowest tunnel, on the bank of Granite creek. This mill is described under the title of Reduction Plants. In two and one-half years the Republic mine has paid dividends to the amount of $382,500.

Mountain Lion.—This mine, next to the Republic, is the best developed property in the district. It is situated about two miles northwest of the town of Republic. On the property there are three parallel veins, with a north and south strike. The central one is the principal vein, and the one upon which the most development work has been done. It occupies a fissure in porphyritic andesite, and has a dip to the west of about 80 degrees.

The ledges have been developed by a long tunnel which cuts through the three veins at a depth of about 300 feet below the surface; by a double compartment shaft, 300 feet deep, which connects the end of the tunnel with the surface above, and by drifts, cross-cuts, winzes and raises which represent in totality several hundred feet.

In the main vein the development work disclosed the presence of an ore shoot 600 feet long, and of a depth not yet determined. At its widest point it measures 18 feet, occasionally being reduced to 10 or 12 feet. The vein filling is apparently all quartz, often resembling flint or hornstone, and usually very compact. Within it there are many small cavities lined with quartz crystals. At most places the walls of the vein are quite distinct, but sometimes the ore is frozen to the walls and does not break off readily. Gold constitutes the chief value in the ore, occurring free, but in an exceedingly fine state. Silver occurs sparingly, one or two ounces per ton being present. No leaching has taken place in the vein, the surface assays being as high as those at a depth. The east vein has a width of seven feet, its depth and length as yet undetermined. Some sulphides are present in this ledge, At the 150-foot level the ore is much oxidized. This ledge has a dip of 60 to 70 degrees westward, and may come into the principal vein at depth. At the surface the two ledges are 160 feet apart.

The 100-ton mill which has been erected to treat the Mountain Lion ore is fully described under the heading Reduction Plants.

Tom Thumb.—The Tom Thumb mine is located one mile east of the Mountain Lion mine and more directly north of Republic. One vein of ore is being developed. It has a northeast and southwest strike with a dip of 45 degrees to the southeast. The ledge has walls of porphyritic andesite, and measures on an average eight feet from wall to wall. The vein filling is quartz, very closely resembling the Republic ore. Eight or nine ounces of silver are present with each ounce of gold.

The development work consists of a shaft, with many drifts, cross-cuts, and winzes, aggregating in all 1,500 feet, and having cost with the mine machinery about $80,000. The main shaft reached the ledge at a depth of 255 feet, the first 215 feet being in sandstone and shale, the last 40 feet in porphyry. The mine machinery consists of a 100 h. p. boiler, an 8-drill compressor, and a 45 h. p. hoisting engine.

Quilp.—This mine is located at the northern border of the older part of the town of Republic, or Eureka as it was once called. The Quilp is at the southern end of a prominent north and south ledge, lying parallel with, and on the east side of, Eureka gulch. This ledge is easily traced northward through six claims, or for a distance of about 9,000 feet. Throughout it has walls of porphyritic andesite.

At the Quilp mine the ledge has a dip to the eastward of about 45 degrees, and a width varying from 3½ to 5 feet. The development work consists of about 2,637 feet, represented by a shaft, with several drifts, cross-cuts, winzes, etc. Ore to the extent of 754 tons has been sold, for which $13,142 have been received. The values are altogether in gold and silver, the gold varying little in amount from the surface downward, while the siver values constantly increase. In the lower workings about 60 per cent. of the total value is in gold, and 40 per cent. in silver. The mine machinery consists of a 7-drill compressor, boiler, hoisting engines, pumps, etc. About $85,000 has been spent in developing the property.

Lone Pine-Surprise.—This mine is located on the same ledge as the Quilp and immediately to the northward. The strike of the vein continues northward and southward with a dip to the east. The width of the ore body varies from 2 to 16 feet. The ore is not dissimilar in appearance from that of the Republic mine. It contains about 5 ounces of silver to each ounce of gold.

Four hundred and twenty-three tons of ore have been sold for which $5,638 were received. The underground development work aggregates altogether 3,285 feet. Up to date the cost of all work done upon the property amounts to $81,125.

Black Tail.—This mine is located on a ledge parallel with and to the east of the Quilp-Surprise ledge, and distant from it about 400 feet. The Black Tail ledge varies in width from 3 to 8 feet. The dip is very irregular as descent is made. The walls are in the main distinct, but the quartz is often frozen to the walls. The quartz often extends as stringers into the adjoining andesite. The vein shows a banded structure that is more pronounced than usual. Thin seams of clay often occur in cracks in the quartz. At the southern end of the Black Tail claim the ledge splits into two parts, one part turning to the left very sharply, the other to the right less sharply. Five stringers come into the ledge from the east, the largest one having a maximum width of three feet.

Assays of the ore show that 10 ounces of silver are present for each ounce of gold. About 300 tons of ore have been sold, 200 tons at $13 per ton, and 100 tons at $20 per ton. About 2,000 feet of development work has been done. The estimated cost of all work done upon the property, outside and inside of the mine, is placed at $50,000.

San Poil.—The San Poil mine is located at the southern end of a ledge which is found on the west side of, and parallel to, Eureka gulch. This ledge has been traced northward for about a mile. On the San Poil property the ledge has a strike of north 30 degrees west, and a dip to the eastward of about 80 degrees. The ore occurs in distinct lenses or shoots, which reach a maximum thickness of 8 feet. While the vein filling is largely quartz, there is more calcite present than is usually found in the Republic veins. Within the ledge an occasional horse is encountered, and one small fault occurs. The walls are well defined, and very firm, so that only a small amount of timbering is required. About 2,200 feet of underground work has been done. Of ore 200 tons have been sold, for which $13 per ton were received.

Ben Hur.—This mine is located immediately to the northward of the San Poil, and on the same ledge. This ledge shows prominently at the surface, and is easily followed. The surface

ore is scarcely weathered and there has been but little leaching. On the Ben Hur the ore occurs in distinct shoots, with areas between of broken wall rock seamed in all directions with stringers of quartz. The ore shoots vary in size, averaging in width from 6 to 8 feet, and one of them was found to be 80 feet long. The ore is chiefly quartz, banded, and usually frozen to the walls. The gold and silver contents are found in the proportion of one ounce of the former to five ounces of the latter.

El Caliph.—This mine is located north of Granite creek, about one and one-half miles northwest of the town of Republic. The ledge has a strike of north 70 degrees east, and a dip to the southeastward at a very high angle. It is a quartz ledge between walls of porphyritic andesite, varying in thickness from one to eighteen inches, averaging about eight inches. The ore is much iron stained at the surface, and sulphides will no doubt be found beyond the zone of surface alteration. Free gold may often be seen in the surface specimens. Eighty-five tons of ore have been sold, yielding $9,000. Only a very small quantity of silver occurs in the ore. Very little development work has been done upon the property, about 450 feet in all, represented by a tunnel and a shaft.

Morning Glory.—This mine is located immediately to the westward of the El Caliph, and is presumably upon the same ledge. The vein has a northeast and southwest strike, and a dip of 45 degrees to the northwestward. The ore here is of a high grade, 55 tons having been sold for $13,807. Tellurium is found, indicating the presence of tellurides of gold and silver. About 1,700 feet of development work has been done, at an estimated cost of $39,000.

Princess Maud.—This mine is located on the mountain side west of the San Poil, and very near the Republic mine. The ledge has a north and south strike with an eastward dip of about 65 degrees. It varies in width from 2½ to 5 feet, with an average of about 4 feet. The walls are of porphyritic andesite, and very well defined. The values are in both silver and gold, the former being somewhat in excess. A pay streak at the 50-foot level is being developed which averages in value about $24 per ton. The development work to date consists of 488 feet of tunnel, a winze of 425 feet, and a drift 710 feet long. The greatest

depth reached is 625 feet. Steam power is employed, the equipment consisting of a Leyner two-drill compressor, Rand drills, boiler, etc. Up to date about $52,000 has been spent in developing the property.

Butte and Boston.—This property is located upon the same ledge as the Princess Maud. The ledge has here also a north-south strike and an eastward dip. The width of the vein averages 6 feet. The average assay value of the ore is about $16 per ton, $14 of which are in gold. About 1,060 feet of underground development work has been done, consisting of two shafts, one 265 and the other 75 feet; two tunnels, one 285 and the other 35 feet, and drifts aggregating 400 feet. About $30,000 have been spent upon the property to the present time.

LINCOLN COUNTY.

Lincoln county lies practically altogether within the domain of the Columbia basalt, a formation in which metalliferous veins do not occur. Along the northern boundary of the county, however, especially near the confluence of the Columbia and Spokane rivers, metamorphic rocks appear which were never covered by the lava, and in these veins of ore occur. A brief description of one of the mining properties of the district is here given.

Crystal.—In the spring of 1896 the Crystal Mining Company, of Spokane, began work upon two ledges located one and one-half miles to the eastward of the mouth of the Spokane river. One of these ledges is nine feet, and the other eight feet, in width. Each has a northeast and southwest strike. In the development of the property three shafts have been sunk having an aggregate depth of 425 feet; drifts have also been driven to the extent of 540 feet. The average assay value of the ore is about $40 per ton in silver and lead. About 500 tons of ore lie on the dump ready for shipment. The company has a 32 h. p. hoisting engine and a 50 h. p. boiler. The total cost of all development work is estimated at $28,000. (John Gray, manager, Spokane.)

OKANOGAN COUNTY.

Okanogan county lies north of Chelan and Douglas counties and west of Ferry. It is one of the largest counties in the state and the one farthest removed from railway facilities. It possesses no features, however, which would make railway construction impossible anywhere throughout the length and breadth of the county.

In its topographical aspects Okanogan county is characterized by considerable diversity. In a general way the southern and eastern parts of the county are regions of broad valleys, rolling hills and level plateaus; the northwestern portion of the county is a district of high mountains, being typical of the rugged parts of the Cascades. The Okanogan river is a very sluggish stream flowing in an old valley remarkable for its breadth. The Methow, especially in its lower reaches, also flows in a broad, fertile valley, and is bordered by rolling hills. Glaciers have passed down both the Methow and Okanogan valleys and have left traces of their former presence in the shape of terraces and moraines. The lower parts of Okanogan county along the Columbia, Okanogan, and lower Methow rivers, possess a rainfall which does not exceed ten inches per year, and as a consequence desert-like conditions prevail and agriculture may be carried on only by the aid of irrigation. In those parts of the county possessing a greater altitude, notably the northern and northwestern portions, the country is forest clad. The western portion of the county is very well forested and is included within the Washington forest reserve.

Okanogan county is largely a region of ancient metamorphic rocks, with large areas of granite. At several places in the county there are small areas of sedimentary rocks which represent the later geological times. These areas are small because they represent deposits made in former lakes. In both the older metamorphic rocks and the younger sedimentaries there have been many intrusions of igneous rock of various kinds which tend to complicate the geological structure.

In nearly all parts of Okanogan county veins of ore occur, many of which are of economic importance. Development work

upon the ore bodies has been in progress for several years, in most instances with gratifying results. The ore for the most part is such that requires smelting in order to extract the precious metals, although some free gold occurs. The absence of easy shipping facilities has militated against the rapid development of the mines. The principal mining districts in the county are those of Wauconda, Myers Creek, Palmer Mountain, Conconully, Moses, Upper Methow, Twisp, and Squaw Creek.

WAUCONDA DISTRICT.

This district is located near the eastern boundary of the county, about twenty miles south of the international boundary and twelve miles northwest of Republic. It is situated at the headwaters of Granite creek, a stream which unites with the San Poil at Republic. The district is practically upon the north-south divide which separates the eastward flowing streams from those whose courses are westward to the Okanogan. The topography of the district is not of the rugged type, the hills and ridges being low and as a rule possessing rounded forms. The yearly precipitation is low, but of a quantity to support a moderate forest growth. The trees are not large and do not stand very close together, yet the timber is in sufficient quantity to meet the requirements of large mining operations for many years.

The oldest rocks of the Wauconda district consist essentially of gneiss, schist, crystalline limestone, slate, and other metamorphics which have been greatly dislocated by intruded masses of granite. Both the metamorphic rocks and the granite often contain within and upon them intruded and extruded masses of porphyritic andesite, and basalt. Some of the hills are capped by horizontal layers of basalt, which seems to have been the last rock outpoured. Granite constitutes the axis of the divide above mentioned. Going eastward from the granite one passes over gneiss, schist, and slate, in beds dipping very steeply to the eastward. To the eastward of the metamorphics a small intrusion of granite is next encountered, followed by porphyry and basalt.

The ore bodies of the Wauconda district which occur for the most part as fissure veins in the metamorphic rocks, are characterized by their great size. The vein filling is quartz, with a little calcite, carrying free gold in a very fine state. In most respects the ore does not differ essentially from much of the ore found in

the Republic district. The Wauconda district takes its name from the mine of that name which was the first located, and is now much the best developed, in that locality.

Wauconda.—The Wauconda property consists of thirty-two claims, twenty-two of them in the main group near the town of Wauconda, and ten in another group about three miles distant. On the property there is a series of wide parallel veins, having a strike a little west of north, and traceable for considerable distances. The two main ledges are the Oregonian and the Wauconda. The main tunnel, No. 5, which runs almost due west, nearly at right angles to the vein, struck the former ledge about 700 feet from the mouth, and left it at 770 feet, while the face of the tunnel, at present 1,025 feet in, indicates that the Wauconda ledge is near at hand. These ledges or mineralized zones, present a very remarkable condition in the magnitude of the mineralized portion of the mountain. The veins run about 30 degrees west of north and dip about 60 degrees, the hanging wall being to the east. Where the main tunnel, which is about 500 feet below the apex of Wauconda mountain, cuts through the first mineralized zone the vein has a width of 152 feet. While most of this is very low grade ore, yet assays never fail to show some gold throughout its extent. One portion of this, of solid quartz from ten to fifteen feet in width that has been drifted upon both north and south, shows values of from $10 to $20 per ton.

The Oregonian ledge, the one which is at present best developed, is encountered in the tunnel at 570 feet and is not passed through until 770 feet is reached. The portion of this from 570 to 700 feet is low grade like the first ledge and is composed of mixed quartz and the slaty country rock. Solid quartz, however, commences at 700 feet and continues to the foot wall. The 40 feet of ore from 700 to 740 feet is the main ore body of the mine. This has been drifted upon to the northward and the southward from a chamber which has been cut at a distance of 726 feet from the tunnel mouth. The south drift has been extended 50 feet, and the north drift 80 feet, thus opening up the ledge for a length of 130 feet. The ore from this ledge has been very thoroughly sampled by small average assay samples, and again by 50 and 100 pound samples worked in the sampling mill. The values obtained varied from $5 to $50, but the greater number ranged from $10 to $20; a general average of

$12 for the part of this ore body already in sight is conservative. The different portions of the ledge opened up by the drifts show a fairly uniform quality and value of ore.

It is expected that the main tunnel will very soon reach the Wauconda ledge. This ledge is partially developed by tunnel No. 4 at about 250 feet below the top of the mountain. In this tunnel drifts have been made on the ledge aggregating 215 feet and two cross cuts have been driven, one westward to the foot wall, 28 feet, and eastward 56 feet toward, but not reaching, the hanging wall. The values encountered were very satisfactory, especially toward the hanging wall. Tunnel No. 1 developed the Oregonian ledge near the surface, as No. 4 did the Wauconda ledge, and as shown by these two tunnels the latter ledge is richer. Therefore it is expected that when the main tunnel encounters the Wauconda ledge it will prove to be another ledge of as great magnitude and value as the Oregonian ledge already described. Besides these ledges, three other large ones have been prospected on the property which the tunnel will eventually develop. The mill which has been erected to treat the ores from the Wauconda mine is described under the section headed Reduction Plants.

MYERS CREEK DISTRICT.

This district lies in the northeastern part of the county, in the drainage basin of Myers creek, and round about the small towns of Chesaw and Bolster. The surface of the country is that of a plateau, having a height of 3,000 to 4,000 feet above the sea, with low hills and ridges lying upon it. The slopes are so gentle that a deep soil has accumulated and outcrops of bed-rock are of rather uncommon occurrence. The soil is very fertile and supports a rich growth of bunch-grass, the precipitation not being large enough to induce forest growth except upon the higher hills.

The rock formation is chiefly granite, with different varieties of eruptive rocks. Some of the ore veins are associated with eruptive masses of serpentine. The ore bodies of the district are usually made up of the common sulphides, iron pyrite, chalcopyrite, galena and sphalerite, with quartz and calcite as the gangue minerals. The ore is of a character that requires smelter treatment in order to obtain the values, which consist of gold and silver with a little copper.

Monterey.—This property, belonging to the Monterey Gold Mining Company, is located three miles south of the international boundary line and four miles west of the Ferry county line. The ledge reaches a maximum width of 35 feet, and carries gold, silver, copper, and lead. The best ore yields assays varying from $50 to $85 per ton. The ore contains a considerable quantity of iron and lime, making it to a certain extent self-fluxing when smelted. A main tunnel 728 feet in length has been driven, striking the vein at a vertical depth of 300 feet. Several shafts have been sunk and a number of drifts made, bringing the total amount of development work up to 1,000 feet. (M. M. Walsh, superintendent, Oakesdale.)

Yakima.—This property is located near Chesaw and belongs to the Yakima Mining and Milling Company. The ore is found in serpentine, either disseminated through it or occurring in ledges. The ledges are several in number, with parallel courses, and as a rule are but a few inches in width. The largest vein varies from four to six feet in width, and contains bands of solid ore. The metallic minerals are chalcopyrite, galena, sphalerite, and iron pyrite, carrying gold and silver. The veins have an east and west strike with a southward dip of 25 degrees.

Review.—The Review Gold Mining Company, of Spokane, has two claims located near Bolster. The ore body lies between walls of granite and slate. The metallic minerals consist chiefly of chalcopyrite and iron pyrite, with quartz and calcite as gangue minerals. The development work consists chiefly of two tunnels which have been driven on the vein, one having a length of 360 feet, and the other a length of 813 feet. There is a large amount of ore on the dump. A smelter test of 50 tons taken from various places on the ledge is said to have given an average assay of $17.20 per ton, the principal value being in gold.

Mary Ann Creek Placers.—On Mary Ann creek, a small stream emptying into Myers creek near Chesaw, placer gold was discovered in 1888, and the placers have been worked in a small way ever since that date. Fourteen claims are located on the creek, nearly all of which are worked each season. The gold occurs from the grass roots downward through the washed gravel to bed rock. About four feet above bed rock a seven-inch seam of clay occurs, immediately above which the gravel is richer

than elsewhere. The gold is coarse, no mercury is used, and nearly all of the gold is caught in the first riffle. No trees or tree-roots are found upon the claims, and hence the ground is easily worked.

PALMER MOUNTAIN DISTRICT.

In this report Palmer mountain district is made to include that part of Okanogan county lying between Okanogan river and Gold hill, and from the international boundary to the vicinity of Loomis. This district came into prominence a number of years ago because of the large bodies of quartz which it contains, but development work has been hampered by the long haul from the railroad that is necessary in order to secure mining supplies and machinery. In spite of every obstacle, however, work on many properties has been steadily carried on, so that in the total amount of its development the district is exceeded by but one or two others in Washington.

Palmer mountain, having a height above the bordering valleys of about 4,000 feet, occupies the central part of the district. This mountain has a very broad base, and slopes so gentle that wagon roads are easily constructed upon all sides of it, except the west. Palmer mountain is surrounded by broad, low valleys, the Spectacle lake depression lying at the southern foot, the Wannicutt lake basin at the east, with Simlahekin creek and Palmer lake as the western boundaries, and the Similkameen river skirting the mountain on the north. To the west of Palmer mountain, and beyond the valley of the Simlahekin and Palmer lake, lies Gold hill and Mount Chapaca, two of the bolder outliers of the Cascades. The region under consideration has a rainfall of but ten to fifteen inches per year, and as a consequence the higher parts only are forested, the remaining areas being covered with bunch-grass and sage brush.

Palmer mountain district is a region of old metamorphic rocks, mainly schist, slate, gneiss, quartzite and crystalline limestone. These formations show conspicuously from about the middle of Palmer mountain eastward to the Okanogan river. At some places, notably at White Rock bluffs, unmetamorphosed sedimentary rocks occur, consisting of conglomerate, sandstone, slate and limestone. These beds are seemingly non-fossiliferous, but from their lithologic resemblance to rocks of determined age found to the east and to the west of them, they are doubtless

of early Tertiary age. Eruptive rocks are very common, mainly granite and diorite, with different kinds of porphyry. Gold hill is a mass of granite, with intrusions of porphyry. The western half of Palmer mountain to the metamorphic contact above noted, is made up of diorite, seamed with porphyry dikes.

The ore veins are essentially of two kinds, quartz veins, and those in which the sulphide minerals predominate. The quartz veins usually carry free gold at the surface, but this disappears with depth and sulphides make their appearance. In some cases enough quartz bearing free gold has been found to warrant the establishment of stamp mills, several of which are found in the district. The sulphide veins consist mainly of pyrrhotite, iron pyrite, sphalerite, and chalcopyrite, with calcite and quartz as gangue minerals. These veins carry both gold and silver, the former affording the larger amount.

In the Palmer mountain district the mining claims have been segregated into large groups, which are controlled and operated by different companies. This arrangement is made possible by the fact that parallel ledges often occur so near together that it is advantageous to develop them as a group.

Palmer Mountain.—The Palmer Mountain Gold Mining and Tunnel Company's group of fifty-six claims forms a compact body on the southwest slope of Palmer mountain, near Loomis, and extends from the base to the summit of the mountain. In the development of this property a main tunnel eight by nine feet in cross section, has been driven in from the base of the mountain, a distance of 4,000 feet. This tunnel is perfectly straight and with no more slope than is necessary to secure good drainage. At the end of the tunnel a vertical depth of 1,400 feet has been attained. The tunnel is all the way in diorite, except for the dikes which were passed through. In the 4,000 feet of tunnel twenty-eight veins of ore were cross-cut, a number of which are small and which do not appear on the surface. Parallel with the dikes, which are older than the veins, are certain shear zones where the rock is much broken and a schistosity is developed. The shear zones are mineralized, which probably took place at the time when the veins were formed.

The power plant of this company is located near the mouth of the tunnel, and consists of an Ingersoll-Sargeant air compressor, air receivers and pipes, three air drills, a 55 h. p. boiler, a

40-inch blower and exhauster driven by a 19 h. p. engine, with the necessary blacksmith and machine shops. On Toats Coulee creek, about a mile and a half from the mouth of the tunnel, the company owns a water power capable of developing 3,000 h. p.

Gold Hill.—This mine is located on Gold hill about three miles west of Loomis. The company owning this mine have altogether eighty-six claims, upon which a number of ledges are found. At the present time the development work is being done largely on one vein, which has an average width of about four feet. This vein has a northeast and southwest strike and a dip of 75 degrees to the northwest. It is a true fissure vein with walls of granite. The vein is filled with massive quartz, occasionally banded with iron pyrite, chalcopyrite, galena, sphalerite, and copper carbonate, carrying gold and silver. About 4,000 feet of underground development has been done, consisting of drifts and crosscuts. Water power is employed to run a 50 h. p. compressor and the saw mill. To secure the proper fall a flume four by four feet in cross section and one mile long has been constructed along the side of Toat's Coulee creek.

Golden Zone.—The Golden Zone mine is located on the Similkameen river, sixteen miles north of Loomis, and three miles from the British Columbia boundary. On the property there are three parallel ledges which outcrop on the face of a granite cliff, which fronts the valley. The one ledge which is being developed has a northeast and southwest strike, with a dip to the northwest varying from 45 degrees to 80 degrees. The vein when followed along its course widens and narrows, varying from a few inches to four feet in thickness. The ore body consists of quartz carrying chalcopyrite, galena, iron pyrite, molybdenite, and a little free gold. A large amount of ore has been removed from the mine and treated in the stamp mill at the foot of the mountain. Whatever free gold the ore contains is caught on the plates, while the cencentrates are shipped to Everett and Tacoma.

Bull Frog.—On the summit and west slope of Palmer mountain and the west slope of Little Mount Chapaca, there is a group of fifty-one claims belonging to the Bull Frog Gold Mining Company. Most of the claims were located about 1889, and active development has been carried on from 1893 to the

present time. Eight veins have had more or less done upon them. They vary in width from eighteen inches to twenty-five feet, and strike northwest and southeast. The total amount of underground work is represented by 1200 feet of tunnels, drifts, etc. There is now on the dump several thousand tons of ore. A test run of ten tons yielded $17 per ton, of which $12 was in gold and $5 in silver. The company has erected a cyanide mill of 60 tons daily capacity, run by steam. (Adelbert Hart, president, Oakland, California.)

Black Bear and War Eagle.—These mines lie adjacent one to another on the northwest slope of Palmer mountain, about four miles from Loomis. There are three veins on the Black Bear, two of which have been worked. On the War Eagle there is but one vein. The Black Bear veins are almost four feet wide; that of the War Eagle is five feet wide. They all strike northwest and southeast, and dip to the northeast. The ore is chiefly quartz, carrying free gold in the oxidized portion of the vein, with sulphides below. It averages in value about $18 in gold, silver and copper, chiefly in the first of these. In the Black Bear about 2500 feet of underground development work has been done, and on the War Eagle 500 feet. In Loomis there has been erected a plant to treat the ore, consisting of a five-stamp mill and a concentrator, all run by water power. The value of the ore mined and sold up to date amounts to $150,000. This sum also represents approximately the amount that has been expended in developing the two properties. (John Boyd, Loomis.)

Tribune.—This property is located on the east slope of Palmer mountain, and embraces three claims. On these claims there are four veins, having an average width of about five feet. They have a northwest and southeast strike with a dip to the southwest. The average assay value of the ore in gold and silver is about $12. About 1400 feet of underground development work has been done, and 40,000 tons of ore have been mined. A ten-stamp mill has been erected on the property. The power employed is a 65 h. p. boiler for the mill, two 15 h. p. boilers for the hoist, and 10 h. p. for running four Frue vanners. (John Boyd, Loomis.)

Whiskey Hill.—The Whiskey Hill group of twenty-one claims lies at the eastern foot of Palmer mountain, nine miles

strike, with a westward dip. The principal values are in silver, those of copper and gold being irregular. The underground development consists of about 2,800 feet of work, mainly represented by a 200-foot shaft with three drifts. About 1,000 tons of ore have been sold for which nearly $25,000 was received. (H. S. Stoolfire, owner, Spokane, Wash,)

MOSES DISTRICT.

This district is located in the southeastern corner of Okanogan county, in the region drained by the Nespelim river and its tributaries. It is one of the newest districts in the state, having been created since the Colville Indian reservation was thrown open to mineral entry in 1898. It is a region of low bunch-grass hills, where the rainfall is slight, and where trees grow sparingly.

Multnomah.—The Multnomah group of ten claims lies three and a half miles northwest of the Nespelim agency. There are ten veins varying from three to seventy-five feet in width. They all strike southwest and northeast and dip to the southeast. They vary in richness from $5 to $50 per ton in gold, silver, copper and lead. A number of small openings have been made, aggregating about 200 feet, and costing about $5,000. (Dr. F. O. Hudnut, manager, Spokane.)

Apache.—The Apache claim is located one mile west of the Nespelim agency. There is one vein on the claim, having a width of twelve feet. It stands nearly perpendicular and strikes east and west. A fifty-foot shaft has been sunk on the vein and a little drifting done, costing all told about $1,000. Five tons of ore have been mined and sold having a value of $700 per ton. Nearly all the values are in silver, but there is a little gold present. (Dr. F. O. Hudnut, Spokane.)

Great Western.—The Great Western group of three claims is situated four and a half miles west of the Nespelim agency and six miles from the Columbia river. About $1,000 has been spent in development work. There is now about 100 tons of ore on the dump assaying as high as $75 per ton in silver and lead. The ores are sulphides and carbonates. (Great Western Mining Company, Spokane.)

UPPER METHOW DISTRICT.

This district embraces the country drained by the Upper Methow, and is one possessing a rugged topography because of its nearness to the summit of the Cascades. The precipitation is sufficient to insure a fine forest growth, the whole district being included in the Washington Forest Reserve. The district is entered usually by way of the open valley of the lower Methow, along which good roads have been constructed.

The district is one of metamorphic rocks, gneiss and schist, with various eruptive masses, often of granite. Thick deposits of sedimentary rocks also occur, consisting mostly of sandstone and conglomerate.

Methow.—On the south fork of the Methow river the Methow Gold and Copper Mining Company has a group of seven claims located on McKinney mountain, upon which some development work has been done. The work has been done mostly upon one vein which is about eight feet wide and which carries a pay streak varying from two to four feet in width. The vein stands almost perpendicular and strikes northeast and southwest. The ore is largely chalcopyrite, and assays from 2.2 ounces to 20.2 ounces silver, and from 3.8 per cent. to 25.5 per cent. copper per ton. Tunnel No. 1 has been driven on the ledge a distance of about 120 feet, and from it a winze 50 feet deep has been sunk to ascertain the dip of the vein. Tunnel No. 2 is now being driven for a working tunnel, and will cut the ledge 300 feet below tunnel No. 1. This tunnel is now in a distance of 165 feet. The estimated cost of all development work, including tunnels, buildings, etc., is $5,000. (B. R. Ostrander, president, Spokane).

Oriental and Central.—These claims are located on a vein six feet wide carrying about $10 per ton in gold. The company has sunk one shaft 60 feet, another shaft 40 feet, and run an adit tunnel 270 feet. Work was begun in September, 1900, and since then $5,000 has been expended in development work. The claims belong to the Oriental Mining Company. (John R. Cassin, president, Spokane).

Goat Creek.—On Goat Creek there is a group of nine claims belonging to the Goat Creek Mining Company, of Spokane. All

the development work has been done upon one vein which is about five feet wide. The vein strikes north 30 degrees east, and dips southeast at an angle of from 60 degrees to 75 degrees. One shaft has been sunk 127 feet and another one 25 feet. An adit tunnel has been driven 350 feet and about 50 feet of drifting done. Up to the present time no ore has been sold. The average value of the ore is gold $2, silver 14 ounces, copper 16 per cent. Altogether about $9,000 has been spent in development work. (John R. Cassin, manager, Spokane).

TWISP DISTRICT.

This district is included within the drainage basin of the Twisp, a river of about thirty miles in length which enters the Methow from the westward. The Twisp rises among mountains varying in height from 6,000 to 8,000 feet, whose slopes are heavily forest-covered. Along the lower course of the stream the bordering mountains are low and rounded, and usually bared of forest but clothed with a luxuriant growth of grasses.

The rocks are in general of the metamorphic class, mainly schist and gneiss, through which project many outcrops of granite. Near the mouth of the Twisp there is a considerable area of sedimentary rocks, consisting for the most part of conglomerate, sandstone, and carbonaceous shale. The latter occurs quite conspicuously in a few places, and it has sometimes been mistaken for outcrops of coal.

Spokane.—This claim is located on the north side of the Twisp, about one and one-half miles from its mouth. The ledge is somewhat irregular and not very well defined, but has an apparent north and south strike, with a steep dip to the westward. It varies from a few inches to three feet in width. The mineral contents of the vein consists of sphalerite, arsenopyrite, chalcopyrite, and iron pyrite, with calcite and quartz. The ore occurs usually in pockets or bunches, occasionally in solid bands. The country rock adjacent to the vein is strongly mineralized, making the walls sometimes difficult to determine.

St. Lawrence.—The St. Lawrence group of four claims is situated at the head of North creek, a tributary of Twisp river. There are two veins upon which work has been done. One is seven and a half feet wide and the other thirty feet wide. They

both strike northeast and southwest and dip 45 degrees to the northwest. The ore averages about $20 per ton in gold, silver and copper. The development work consists chiefly of a shaft, a tunnel, and an incline, costing all told about $5,000. (W. R. Marvin, Spokane.)

SQUAW CREEK DISTRICT.

This district lies about Squaw creek, a small stream flowing from the westward into the Methow at a point about nine miles above the mouth of the latter river. Situated as it is in the valley of the Methow and near the Columbia, the district is one of low altitude, with a surface made up of rolling hills and gentle slopes. Only the higher parts are forest-covered, the evergreen growth being somewhat sparse, but sufficient for ordinary mining operations.

The prevailing country rock of the district is gneiss, with eruptive masses of the granite type. The veins of ore as a rule have been deposited in pronounced fissures, the walls of which are of sufficient prominence to be readily identified. The vein filling is usually composed of quartz and calcite as gangue minerals, with iron pyrite, chalcopyrite, galena, arsenopyrite, tetrahedrite and sphalerite. The principal values are in gold and silver, the gold occurring both free and as a telluride. As a rule the ore is not uniformly distributed throughout the veins, but occurs in well-defined chutes. The ledges of the district in general have an east and west strike, standing about perpendicular or dipping a few degrees to the northward.

Hidden Treasure.—The Hidden Treasure Mining and Mill ing Company has a group of six claims on the east slope of Johnson mountain, about one mile north of Squaw creek, and two miles west of the Methow. The Hidden Treasure vein has a strike of north 60 degrees west with a dip of 60 degrees to the northeast. It is a true fissure vein with walls of gneiss. It is from two to four feet in width, except where the ore chutes occur, when a width of eight to ten feet is noted.

The ore in the Hidden Treasure vein consists chiefly of chalcopyrite, galena, sphalerite, and iron pyrite, with quartz and calcite as the gangue minerals. The values are chiefly in gold and silver, with a small amount in copper. The gold occurs in

small amounts as free gold, and to a small extent in the form of sylvanite.

Development work on this property was begun in 1896. Two tunnels have been driven on the Hidden Treasure ledge, an upper one having a length of 200 feet, and a lower one with a length of 260 feet. From the second tunnel a winze has been sunk to a depth of 50 feet, and from the bottom of the winze drifts and crosscuts aggregating 80 feet in length have been driven. Some ore has been stoped out from one of the ore chutes, about 290 tons in all. Of this, 90 tons has been shipped to a smelter, for which $67 per ton was received.

Highland Light.— This mine, owned by the Highland Light Mining Company, is situated immediately west of the Hidden Treasure, and on the same ledge. The ledge has been developed by a shaft 170 feet deep, which cuts through an ore chute dipping eastward. The first 50 feet of the shaft is in ore. At the 25-foot level a drift 20 feet long was run and the ore stoped out; at the 50-foot level another drift 45 feet long was made, and some of the ore taken out from here assayed $90 per ton in all values; at the 100-foot level the vein showed two and one-half feet of good ore, and a drift was run 20 feet to the eastward. At the bottom of the shaft drifts were run in both directions. On this level the ledge averaged three feet in thickness, and the ore assayed from $40 to $50 per ton. (John D. Atkinson, Olympia.)

Standard and Louisa.— These claims adjoin the Hidden Treasure group. The ore vein varies from three and a half to five feet in width. It has an east and west strike and dips to the north. The ore that has been mined averages in value $24 per ton. Only a small amount of development work has been done on the ledge. (James West, president, Seattle.)

Henrietta.— On the south side of Johnson mountain is the Henrietta group of four claims. The vein of ore varies from three to five feet in width. It has an east and west strike, and dips to the northward. The ore assays on an average about $25 per ton in gold, silver and copper. In developing the property one tunnel of 120 feet has been driven, and a shaft has been sunk to a depth of 40 feet. (J. M. Woollery, Spokane.)

Hunter.— This property has a vein of ore which varies from three to nine feet in width. It has an east and west strike, and dips to the northward at an angle of 88 degrees. The average assay value of the ore is $32 per ton, in gold, copper and silver. The development work consists of open cuts, shafts, and tunnels, representing an outlay of $8,000. About 400 tons of ore are now ready for shipment. (James E. Blackwell, president, Hunter Mining Company).

Tom Hal.— This mine, the name of which has recently been changed from the Friday mine, is on a group of five claims. The ledge varies in width from four to ten feet, the richest ore having been encountered in the narrowest part. The ore consists chiefly of iron pyrite, chalcopyrite, and arsenopyrite. It is essentially a gold ore, but carries a little silver and a small percentage of copper. Ten tons of selected ore when shipped to the Everett Smelter yielded $70 per ton. In the underground work a tunnel 110 feet in length was driven, crossing the ledge at this point. A drift of 100 feet was next made, and from the end of this a winze of 100 feet was sunk. From the bottom of the winze drifts of about 70 feet were run in both directions. (John D. Atkinson, Olympia).

Bolinger.— This property, consisting of five claims, is situated on the south fork of Gold creek, two and one-half miles west of the Methow river. There are two parallel ledges on these claims two hundred feet apart and much alike in character. The larger or main ledge is four and a half feet wide on the surface and seven feet wide at the bottom of a ninety foot shaft. This is a true fissure vein, with walls of gneiss. The vein filling is arsenopyrite, galena, chalcopyrite, and iron pyrite, in a quartz gangue. The vein has a strike of N. 30 E., and a dip of 45 degrees to the southeast. In the development work of the property a tunnel four hundred and fifty feet in length has been driven which strikes the two parallel ledges at distances of 235 feet and 450 feet respectively from the mouth of the tunnel. The first ledge is tapped at a distance of 105 feet below the surface and assays from five dollars to fifty-four dollars in gold, and is eight feet in width. The second or main ledge, which is crosscut by the tunnel at a vertical depth of 225 feet, is ten feet wide and carries ore that averages by smelter tests twelve dollars per ton.

About thirty or forty per cent. of the values are in silver and the rest in gold.

Independence.—This property is located on the south fork of Gold creek, very near the Bolinger mentioned above. The ledge varies in width from four to eight feet, and may be easily traced on the surface for a distance of 800 feet. It is a fissure vein with walls of gneiss. The metallic minerals are iron pyrite, arsenopyrite, chalcopyrite, and molybdenite, in a quartz gangue. Occasionally the metallic minerals occur as solid bands which often reach a thickness of eighteen inches. The alteration in the vein due to weathering is slight, and the honeycombed quartz of the surface gives way to unchanged ore at a depth of a few feet. The strike of the vein is about north and south, with a dip of 45 degrees to the westward. The assays of the ore that have been made show values of from $5 to $10 per ton.

WHATCOM COUNTY.

Whatcom county lies in the northern tier of counties, and extends trom the summit of the Cascades westward to the Gulf of Georgia. The western and eastern parts of Whatcom county present marked contrasts in many ways. The western one-third of the county has but a slight elevation above the sea, is characterized by wide alluvial valleys and low hills, and is crossed in all directions by railways and wagon roads. On the other hand the eastern two-thirds of the county is a region of high mountains which possess an extremely rugged character, abounding in deep canyons and sharp divides, and into which trails and roads are built with difficulty.

In the mountainous part of Whatcom county many varieties of rocks are encountered. Gneiss, schist, slate, crystalline limestone and other metamorphics commonly occur. Associated with these are masses of igneous rocks of both intrusive and extrusive origin. In the western part of the mountainous district stands the bold cone of Mount Baker about which volcanic rocks abound.

Although metalliferous deposits have been found in many parts of the mountainous district of Whatcom county, the ledges which have received the most attention are those which are located to the northward of Mount Baker, in the Mount Baker district, and those which are located in the neighborhood of Barron in the Slate Creek district. A brief general description of these districts, with some statements regarding the chief mines and claims within them, will now be given.

MOUNT BAKER DISTRICT.

BY D. A. LYON.

The Mount Baker mining district is situated on the head waters of the north fork of the Nooksack, on the western slope of the Cascades, and includes all the territory which lies immediately north of Mount Baker. On account of the lateness of the season at which our party reached this district, in the early autumn of 1901, and having but a limited time at our disposal, it was found possible to visit only the most important camps. As a result this report is to be considered as wholly preliminary in its nature and will be enlarged upon as soon as more field work can be done.

The district is reached by Maple Falls, which is the present terminus of the Bellingham Bay & British Columbia Railroad. From Maple Falls there is a good wagon road to Shuksan, a distance of about 20 miles. From Shuksan, the Mount Baker Mining Company, owning the Post-Lambert group, has constructed a well built trail to its properties, and in doing so has made it easier to get to those prospects and mines lying to the northwest of Shuksan and in the vicinity of Twin lakes. Those properties which are located to the east and south of Shuksan are for the most part tributary to the state trail.

As may be inferred, nearly all of the prospects and mines of the Mount Baker district are located in the high Cascades, the Post-Lambert group, at an altitude of about 6,000 feet, being the highest of any of the developed mines. Here the snow comes early and stays late, and falls to a great depth. The water supply is plentiful all the year around, and in most cases is in such quantities and so located as to permit of its being utilized for power. In many cases there is an abundance of timber for mining purposes, although some of the mines are lo-

cated at altitudes where timber is scarce, or are above the timber line altogether.

Although over 3,000 quartz claims have been located in the Mount Baker mining district, yet only a few of these have been developed into mines. The principal ores of the district are gold and copper bearing. The gold is present as free gold, and occurs in white quartz, or is present as a telluride, while in other places it is found associated with gold bearing sulphides in veins of bluish grey ore which contains much lime. Again we find large bodies of slate with kidney quartz, which occur as masses, with no well defined hanging or foot wall.

Post-Lambert.—This is one of the best developed properties in the district. It includes a group of eight claims located on the southern slope of what is known as Bear mountain, and to the east and south of two small mountain lakes, known as Twin lakes, which are about twenty miles west and somewhat north of Mount Baker, and are about thirty-six miles southeast of Chilliwack, British Columbia. The property is owned by the Mount Baker Mining Company, the offices of which are in Portland, Oregon.

In developing the property most of the work has been done on the Lone Jack ledge, where a tunnel or inclined shaft has been driven on the outcrop and follows the ledge in for a distance of 140 feet. To the east of the outcrop on a level at a vertical distance of 100 feet below the opening of the inclined shaft, a crosscut is being driven, in order to intersect the vein, which will be done at a distance of about 475 feet. Open cuts have also been made on the Lone Jack ledge in several places, and all of these disclose a well defined vein, and show the presence of free gold and tellurides. The ledge has a north and south strike, with walls of slate. It outcrops for a distance of about 2,500 feet, and has been thoroughly sampled for a distance of 1,200 feet, the average width in this distance being two and one-half feet. From two hundred and eleven free milling tests which were made on this ore, the value in free gold was found to be on an average $28, while numerous fire assays made on the same show it to have a value of $32 per ton. This difference is due to the presence of tellurides, which, being base, are not amalgamable. These will be treated by some other process, preferably by smelting.

There is being constructed on the property a ten stamp mill for the purpose of treating the ore from the Lone Jack ledge. It is intended to carry the ore from the mine down to the mill-site by means of an aerial tramway, the materials for the construction of which are now on the ground. The mill-site is at an elevation of about 2,000 feet, while the mine is at an elevation of about 6,000 feet. It is intended to stamp the ore and remove as much of the gold as possible by amalgamation, and then treat the tailings by concentrating them, in order to recover the non-amalgamable tellurides.

Great Excelsior.—This property is located near the Nooksack, 14 miles from Maple Falls, on the road to the Post-Lambert properties mentioned above.

The Great Excelsior ledge, the exact width of which has not been determined, preserves its character for several hundred feet along its outcrop. It occurs apparently at the contact of slate and porphyry, the former being the hanging wall, and has a strike that is northeast and southwest. The ledge is composed chiefly of quartz and dolomite. Throughout this mass the metallic minerals occur in a finely disseminated state.

Very little development work in the way of prospecting shafts and tunnels has been done on this property, as it was hardly considered necessary, since large masses of ore are already exposed. In one place the hanging wall of slate has been eroded by the creek, leaving the ledge faced up to a considerable height. As to the value of the ore the writer was informed that in no place on the ledge had rock been found, although they had tried to do so, which assayed less than $1.50 per ton. The surface of the ore body is well oxidized, and the values are less than those which are obtained by going in on the same. From tunnels which penetrate the face of the ledge and which have been driven in to a distance of 15 to 30 feet, it is found that at this distance from the surface the mass is crossed in every direction by stringers of pyrites and white quartz, and that these stringers often carry very high values, in no instance assaying below $200 per ton, and often going as high as $500 or $600 per ton. At first sight the ore has the usual appearance of a quartz and sulphide ore, but on examination it is found to contain gold and silver which occur apparently as tellurides, but combining in a manner which is not yet understood, and so gives an uncommon

occurrence of these metals. No free metals are found, and the gold and silver values are about equal; that is, in dollars and cents.

On the strength of what seems to be so spendid a showing, the company owning this property has during the past year devoted all its energy to the work of installing the necessary machinery for the treatment of the ore. The method of getting out the ore will be by open cuts, it being proposed to drive a tunnel into the ore body, and on the floor of this tunnel to construct tramways. The ore will be quarried down from either side of the open cut, dumped into tram cars, and sent directly to the mill for treatment.

Nooksack.—This property was located in 1898. It is situated on a dike which is 315 feet wide, and it is said that the same has been traced for a distance of several miles. The ore is a gold bearing sulphide, and is of a low grade, assaying $3.50 per ton, but to all appearances there is a large amount of it.

The company owning this property have developed it to a considerable extent and now have in place a four-stamp mill and other necessary machinery, and would have begun active operations during the summer of 1901, but were delayed by the late arrival of some pipe from San Francisco, which will be used to conduct water to the mill for power purposes.

Terra Alta.—This property, which is owned by the Terra Alta Mining Company, of Whatcom, is situated on the south extension of the Post-Lambert group of claims on Bear mountain. More or less development work was done on this property during the summer of 1901. About 100 feet of tunneling was driven which opened up a 14-foot vein which is said to carry values in sulphides to the amount of $306 per ton, and another vein 12 feet wide which bears a close resemblance to the Lone Jack lead and is thought to be an extension of the same. It is said to be remarkably rich in gold, some of the values occuring as tellurides.

Trails have been built to the mine, and cabins erected, and during the summer of 1902 the company owning the property expect to install the necessary machinery for the proper exploiting of the mine and for the treatment of the ore.

Saginaw.—The Saginaw claims were located in the early part of 1901, and during that summer two tunnels were driven on the

property, one of 60 feet, cross-cutting a three and one-half-foot ledge, which is said to carry high values, and another tunnel of 37 feet. A shaft was also started and sunk to a depth of 12 feet. On the surface the vein outcrops as small stringers and has been traced for several hundred feet. The values are in copper and gold.

Pierce.— The Pierce group consits of ten claims which are situated on Silica creek and about five miles from the Post-Lambert property. These claims were located in 1889 and in the spring of 1901 active work was begun on their development. Two shafts were sunk, one of 40 feet in depth, another of 50, and about 60 feet of tunneling was driven. The vein has an average width of about three feet, and is said to have been traced for several thousand feet. The values at present are principally in free gold, and give an average assay of about $12. The company owning these claims expect to begin the work of installing mill machinery during the summer of 1902.

Lone Star.— These claims are located on Swamp creek. During the summer of 1901 two tunnels were driven on the property, one of 68 feet, and another of 20 feet. The ore body is a white quartz vein about 25 feet wide, and parallel with it is a grey quartz vein whose exact width has not been determined. The gold values occur as tellurides and sulphides.

SLATE CREEK DISTRICT.

This district is situated in the extreme eastern part of Whatcom county, in the territory drained by Slate, Mill and Boulder creeks. These streams are tributaries of Ruby creek, which in turn is a tributary of the Skagit river. The district is reached in two ways, either by way of the Columbia and Methow rivers to the headwaters of the latter and then over the summit of the Cascades, or else by following up the valleys of the Skagit river and Ruby creek.

Situated as it is in the very heart of the higher Cascades, Slate creek district possesses a very rugged topography. The snowfall is excessive and makes ingress and egress quite difficult or even impossible at times during the winter season. The numerous streams abound in waterfalls and latent water power occurs everywhere. The higher peaks and divides rise above

the timber line, but in the valleys there is ample timber for all the demands of the mining industry.

The ledges of the district occur in two distinct formations. One of them is a black slate, containing numerous quartz veins, usually very thin, which run parallel with the cleavage. This formation extends from the mouth of Slate creek almost to its head-waters, and forms the Slate creek range. The cleavage of the formation in this district is almost north and south, and is parallel to the stratified sandstones, shales and limestones to the east of this area. These last named form what Professor I. C. Russell * calls the Similkameen formation, which embraces an area about 15 miles east and west, extending northward beyond the international boundary line, and southward beyond Crater pass. This area is composed mainly of sandstones, shales and limestones, with quartzite and minor quantities of conglomerate and breccia near the bottom.

In structure the series of rocks lies in closely compressed folds, having a north and south trend, with dips inclined in places, while in others the beds stand nearly or quite vertical. On Gold ridge, which is to the north of Crater pass and immediately east of the summit, in Okanogan county, the rocks dip eastward in such a manner as to indicate that the folds have been overturned to the west. At this point the dip of the strata eastward is at an angle of about eight degrees, but to the north of this the dip increases and soon becomes vertical. The underlying member of the Similkameen series is a hard, nearly white quartzite, changing, as at the Eureka mine, to conglomerate and breccia. Above the quartzite come slates, sandstones, shales and limestones. At the base of Gold ridge is a thick bed of bluish sandstone. This has been penetrated by tunnels which the Gold Ridge Mining Company have driven in the St. Paul and Minneapolis claims.

In many places the Similkameen formation is cut by dikes which trend north and south. On the Minneapolis and St. Paul claims one of the dikes is exposed at the entrance to the tunnel on these claims. It is three to four feet thick, stands nearly vertical, and cuts the sandstones which dip eastward at an angle of about eight degrees. There are numerous other dikes of this kind in the district which have an approximately vertical posi-

* Russell: 20th Ann. Rep. U. S. Geol. Survey, Part II, p. 114, 1898-9.

tion, are light in color, of porphyritic structure and for the most part have a north and south trend. In the region of Gold hill, and also in the vicinity of Windy pass, at the head waters of the east fork of Slate creek, there are numerous east-west fissures which cut the rocks at right angles to the longer axes of the folds, and which have been filled with quartz containing free gold. It is on these veins that the Eureka, Mammoth, Tacoma, Gold Ridge, and many other mining properties are situated.

Eureka.—This mine, owned and operated by the Eureka Mining Company, is situated on the head waters of the east fork of Slate creek, immediately north of Barron, about fifteen miles south of the international boundary line, and about one mile west of the summit of the Cascade mountains. The ore is found in lenses, or pockets, and occurs as a conglomerate. It carries $8 to $10 per ton in gold values, part of which is free, while part is associated with sulphides. Streaks are found containing very rich sylvanite ore.

In order to reach the ore body a tunnel 240 feet in length was driven in on the ledge, and from the end of this a shaft was sunk 65 feet. The ore is hoisted up through this shaft, taken out through the tunnel, and then sent down to the mill by means of a gravity tramway. In the treatment of the ore it is fed into a ten-stamp mill where it is crushed to pass a 40 mesh screen. The stamps have a drop of seven inches, and fall at the rate of 104 drops per minute. The product of the stamps is then passed over amalgamated plates, and is concentrated by means of two Wilfley tables. From the Wilfley tables the tailings pass over canvas slime tables for the purpose of removing any valuable particles which may have escaped the concentrators. However, it is not possible to save all of the values, as about $1.60 per ton is lost in the tailings.

Mammoth.—The Mammoth mine is located at Barron, near the headwaters of the east fork of Slate creek, one-half mile west of the summit of the Cascades. The vein upon which the Mammoth is located is from two to four feet in width with a northward dip of 60 degrees, and a strike about east and west. The gold is found in a white quartz, and is partly free and partly in combination with sulphur and tellurium. The average assay value in gold is about $20 per ton. The mine has produced to date gold to the value of $25,000.

The ore body was opened up by driving a tunnel in on the vein, crosscutting the same, and then following the vein. Only one level has been driven, and this for a distance of about 1,800 feet. Air-driven drills are now used in taking out the ore. After the ore is taken from the mine it is sent to the mill by means of an aerial tramway, as the mill is quite a little lower than the mine. The former process used in treating the ore is that of crushing and then stamping in a five-stamp mill. The product of the stamp battery was then passed over amalgamated plates whereby the free gold was extracted by amalgamation, and the tailings were then concentrated for the non-amalgamable values. As a large amount of values were lost by this method of treatment, the mill and mine were closed during the summer of 1901, and arrangements were made for the installation of new mill machinery, the contract for which has been let and the same will be put in place during the summer of 1902.

So far the owners of the property have spent about $50,000 in developing the same. With better facilities for treating the ore, and with a mill that will save a reasonable percentage of the values, it may confidently be expected that the Mammoth will become a paying mine.

Tacoma.—This property, owned by the Gold Standard Mining Company, has approximately the same location as the Mammoth, being a little to the west and north of the latter. The strike of the vein which is being worked is almost east and west, and dips about 60 degrees to the north. As far as it has been exposed it has an average width of about two feet. About 100 feet to the north is another ledge which is parallel to the one which is being developed. The character of the ore is much the same as at the Mammoth, the values occuring in white quartz both as free gold and as tellurides.

Gold Ridge.—The claims of the Gold Ridge Mining Company are located practically on the summit of the Cascades, but mainly on the headwaters of the Methow river, about ten miles south of the international boundary line. Part of the claims lie in Whatcom county and part in Okanogan county. They were discovered in 1893, at the time of the discovery of the Eureka and the Mammoth, but work was not begun on them until 1897. On the property there are two distinct sets of parallel ledges.

One set of four has a north and south strike, which is parallel with the mountain, while the second set of three veins has an east and west strike with a northward dip. The average assay value of the ore is about $10 per ton, a part of which occurs as free gold and the remainder in combination. It resembles in general the other ores of the district. So far only prospecting work has been done on the claims. This consists of 830 feet of tunnels, shafts, raises, the estimated cost of which has been about $20,000.

Ninety-Nine.—This property, owned principally by Charles H. Ballard, of Barron, consists of 11 claims, located on Crater mountain. The ledge on which the group is located is about four feet in width, with a pay streak of about two feet. The ore has yielded some very high assays, the values being in free gold and tellurides. The ledge occurs between walls of slate and quartzite, and is well defined. So far only prospecting work has been done on the property, a cross-cut tunnel having first been driven to the ledge, a distance of 240 feet, and then drifts were made.

Anacortes.—This property consists of seven claims situated on the Cascade branch of West Canyon creek. Four of the claims are located upon one vein and three upon a parallel vein. So far only development work has been done upon the property, and this chiefly upon the Anacortes and Tip Top claims. At the time this group was visited by the writer, drifts had been run on three different levels. The lower tunnel was in a distance of 310 feet. One hundred feet above this another had been run 100 feet, and about twelve hundred feet above the middle drift, another drift had been started and was in 90 feet. The ore body shows up well in all of these drifts and the walls are quite sharply defined.

The principal ledge in the group is one of quartz carrying free gold, tellurides and sulphides. Its outcrops can be followed for a long distance, and can be seen on both sides of the mountain through which it cuts. Its average width is 2 feet, and the widest part uncovered is 13 feet. Its strike is about 10 degrees west of north and it has a dip of 70 degrees to the southwest. Its hanging and foot walls are both of slate, but in the upper tunnel about 14 inches of conglomerate occurs in the vein on the hanging wall

side. The assay value of the ore ranges from $8 to $300 per ton, and some very high assays have been received on picked specimens.

North American.—The North American Mining and Milling company owns a group of nine claims, situated between Boulder and Mill creeks, at an elevation of about 4,300 feet. These claims are located on lodes which show up remarkably well at the surface, and wherever drifted upon have given high values upon assaying. The values occur in a white quartz which is more or less oxidized at the surface, and it is presumed that the ore will become base at a depth. The strike of these veins is nearly east and west. At the time this property was visited by the writer, the development work which had been done consisted of three tunnels and five drifts. One of these tunnels was 100 feet in length, another 40 feet, and another 35 feet. One of them was being driven in a clayey formation which, when panned, showed the presence of an appreciable amount of free gold.

Monto Cristo.—This property consists of two claims on Canyon mountain, to the north of Canyon creek. The claims are located on two north and south ledges each of which has a width of about seven a half feet, and which yield an average assay of about $6.

SKAGIT COUNTY.

Skagit county lies between the counties of Whatcom on the north and Snohomish on the south, and extends from the summit of the Cascades westward to tidewater. As was the case with Whatcom county, the very mountainous character of the eastern part of Skagit county is in great contrast in every way with the alluvial plain of the western part. The low plain of the coast, however, is continued eastward in the wide alluvial valley of the Skagit, which extends to within a few miles of the extreme eastern limits of the county.

The mountainous area of Skagit county is largely one of metamorphic rocks, chiefly schist, gneiss, and crystalline limestone. Granite occurs, as well as many varieties of younger ex-

trusive and intrusive rocks. Prospecting for metallic minerals has been done over large portions of the mountainous section of the county and many ledges have been found. Data is at hand for reports upon but two districts of the county, Thunder creek and Bald mountain, and some brief statements about these will now be given.

THUNDER CREEK DISTRICT.

By D. A. Lyon.

This district is situated in the extreme northeastern corner of the county, adjacent to the summit of the mountains, and very near the Whatcom county line. It lies within and immediately about the basin of Thunder creek, a tributary of the Skagit which enters that river about twenty-five miles above Marblemount.

Ledges of ore were discovered in this district a number of years ago, but it is only recently that active development work has been undertaken. The country rock of the district is chiefly granite, with dykes of porphyry. The altitude is so great that the rocks are generally bare of vegetation and soil, so that veins of ore may be readily seen and traced.

Willis and Everett.—This property, consisting of nine claims, is owned by the Baker Mount Mining Company, of Seattle. It is located in Silver basin, on the south fork of Thunder creek. There are on the property three well defined veins, two of which are parallel and have a northwest and southeast strike. The third vein has a north and south course, and cuts the other two.

The values of the upper ledge, which is from eight to twelve feet thick, run very high. It is not unusual for an assay to yield $200 in silver and $9 in gold per ton. Picked samples have run as high as 3,600 ounces of silver per ton.

The lower ledge, four to ten feet in thickness, runs very high in silver, together with some gold. On this vein there is an open cut of 50 feet on the ore body. The foot wall is granite; the hanging wall porphyry. Below these veins are other ledges on which some work has been done.

Lakeside.—This property is located on the south side of Silver basin, on the south fork of Thunder creek. The ledge is about three and one-half feet wide, with both its hanging and foot walls of granite. Its strike is north 50 degrees east, with a

vertical dip. The average assay value per ton is about $36 in gold and about $20 in silver.

Great Northern.—This property is located immediately adjoining the Lakeside, described above. The ledge is 26 feet wide, with a strike of north 50 degrees east, and with a vertical dip. The vein carries gold, silver and zinc.

As these properties are all quite close to one another, it is proposed in the near future to build a concentrator, which will be so located that it can treat the ore from all the mines of the basin.

BALD MOUNTAIN DISTRICT.

Bald Mountain.—This mine is located fifteen miles southeast of Sedro-Woolley, near the summit of Bald mountain. It is easily reached by wagon road and trail from Clear Lake. The country rock is schist and slate, with a large dyke of diorite cutting these formations. The slate is massive and contains bands and irregular masses of lime-soda feldspar scattered through it. The mine itself is located in section 17, township 34, range 6 east, on both sides of the summit of the mountain. There are a number of veins all badly weathered at their outcrops. The strike of the main ledge is north twenty degrees east, and the dip is southeast fifty degrees. The hanging wall is schist, the foot wall has not yet been found. The ledge is supposed to be about sixteen feet wide. One assay of the ore gave thirty per cent. copper and three dollars in gold. The development work that has been done consists of two shafts, one 60 feet and the other 50 feet in depth, with a crosscut tunnel of 420 feet in length. The property belongs to the Bald Mountain Mining Company, of Clear Lake.

CHELAN COUNTY.

Chelan county lies between the Columbia river on the east and the summit of the Cascades on the west, with Okanogan and Kittitas counties as its northern and southern boundaries, respectively. The surface of the county has a normal slope from the Cascade summit, with an approximate elevation of 7,500

feet, southeastward to the Columbia river, where the elevation above sea is from 600 to 700 feet only.

Chelan county is naturally divided into three drainage basins, those of the Wenatche, Entiat, and Chelan rivers, the first and last heading in the main divide of the Cascade range, and all flowing southeastward to the Columbia. Chelan river is the outlet of Lake Chelan, a very beautiful body of water occupying a great cleft in the granite mountains. The deep depression occupied by the lake extends northwestward beyond its head and is there known as the valley of the Stehekin river.

Chelan county is for the most part a region of ancient schists and gneisses, with large areas of granite. Intrusive rocks, in the form of dikes of andesite, diorite-porphyry, and acid quartzite-porphyries are of common occurrence. The basalt of the Columbia plain extends a little way into the southeastern corner of the county. Between Leavenworth and Mission, and extending northward and southward for several miles, is found a massive sandstone of Tertiary age, which represents an extension of the Swauk sandstone.

HORSESHOE BASIN DISTRICT.

Horseshoe basin is situated at the headwaters of the Stehekin river, very near the summit of Cascade pass. It is reached by a short trail leading off from the main trans-mountain trail, the latter leading up the Stehekin, over Cascade pass, and down the Skagit by way of Marblemount. This so-called basin is a great natural amphitheatre carved out by glacial action. It has an elevation of about 6,000 feet, and contains so much ice and snow that mining operations are mainly confined to the summer months. The mountain peaks which surround the basin are nearly destitute of timber, but in the valleys there is an abundance of hemlock, cedar, fir and pine, sufficient for all mining purposes. The streams furnish an abundance of water power, which can be harnessed very easily and made to do all the hoisting and lighting around the mines.

Gneiss and schist, with intrusions of granite and diorite, constitute the chief rock formations in the Horseshoe basin region. The ledges of ore are of unusual size, and are composed essentially of galena and chalcopyrite carrying gold and silver.

Black Warrior.—This claim lies between Horseshoe basin and Doubtful lake. It is on a well defined east and west ledge,

varying in width from 20 to 30 feet, with a pay streak from two to eight feet wide. The vein contents are galena and chalcopyrite, with good silver values.

Davenport.—This claim is on a ledge parallel to the Black Warrior, and between the latter and the head of Horseshoe basin. The ledge in some parts attains a width of forty feet, and stands about perpendicular. Development work on the property is much hindered by the great quantities of snow and ice which covers the ground throughout the year. The mineral contents of the ledge are chiefly galena and chalcopyrite. A ton of the ore shipped to a smelter gave a return of $69 in lead, copper, silver and gold.

Texas Jack.—This claim, now owned by the Chelan Copper Company, is located in the upper Horseshoe basin. The width of the vein between walls equals 30 feet in places, with a pay streak of about 20 inches. The vein has a northeast and southwest strike, with a dip of 75° to the northwest. The principal values are in copper and silver.

BRIDGE CREEK DISTRICT.

Bridge creek comes into the Stehekin river from the north bout fifteen miles above the mouth of the latter stream. This creek drains a large area of granite, gneiss and schist, in which ledges of ore occur. In the district many claims have been staked, but upon none of them has development work assumed large proportions.

Butte.—This property, owned by the Butte Gold, Silver and Copper Mining Company of Spokane, is located on Bridge creek about twenty-five miles from the head of Lake Chelan. In the development of the property it has been necessary to build a good many miles of roads and trails. There are two veins upon the property and a tunnel has been driven upon each vein, one tunnel being at the present time 56 feet long and the other 42 feet in length. One vein which was stripped for 36 feet shows a width of 8 feet between walls.

RAILROAD CREEK DISTRICT.

Railroad creek heads among the high mountains constituting the summit of the Cascades, and flows eastward into Lake Chelan at a point about twelve miles from the upper end of the

lake. It is well fed by snows and glaciers, and as it makes a descent of over 4,000 feet in 20 miles it affords an abundant water power. The valley sides are covered with a goodly forest growth until the timber line is reached well toward the head of the stream. Throughout its course Railroad creek flows in granite, in which at several places veins of ore have been discovered. The two most prominent ledges that have been found are known as the Crown Point and the Holden.

Crown Point.—The Crown Point property is located near the head of Railroad creek about seventeen miles from Lake Chelan. The vein appears at the surface on the face of a bold granite cliff and is reached with some difficulty. It lies almost flat, dipping to the westward at an angle of five or six degrees. It has a width of from two to three feet and is composed chiefly of solid quartz with small quantities of molybdenite disseminated throughout the gangue. As a rule the molybdenite occurs in well formed crystals having the form of hexagonal pyramids and with diameters reaching an inch or more in length. Some times the molybdenite occurs in irregular masses having diameters of three or four inches. At the end of the short tunnel which has been driven on the vein chalcopyrite has made its appearance, and occasionally shows itself in conspicuous masses.

Holden.—On Railroad creek about eleven miles up the valley from Lake Chelan is the Holden group of three claims. The ledge outcrops upon a rather steep mountain side where the ore body has been laid bare by the snow slides which have swept down the mountain, carrying along with them all of the loose surface materials. The ledge shows very distinctly along the outcrop for a distance of several hundred feet. It is in the nature of a replacement vein where the granite which constitutes the country rock has been impregnated and largely replaced by chalcopyrite and iron pyrite. In the joints of the granite solid bands of ore occur. Between the joint planes the more soluble constituents of the granite have been removed and the metallic minerals above mentioned have taken their places. The vein has, therefore, no proper walls and the zone of replacement is somewhat illy defined, passing gradually from the rock containing a large percentage of ore to the rock which contains none at all. At one place a measurement made at right angles to the

strike and across the zone of replacement showed the latter to be 200 feet, at other places it is of course much narrower. The ore values are in gold, silver and copper. At the present time the extent of underground development is about 300 feet.

PESHASTIN DISTRICT.

BY A. E. KNAPP.

The Peshastin Mining District is in the southern end of Chelan county on the eastern slope of the Cascades. It lies between the ridges that define the water shed of Peshastin creek from Ingall creek on the north, to the summit on the south. Shaser, Scott, Ruby and Peshastin creeks afford abundant water power. Their channels are primarily the result of glacial action, the subsequent erosion having done little more than to concentrate the glacial debris and leave some good placer in the main creeks. The hills are generally well covered with fine timber, some of it excellent for lumber.

The geology of the district has been carefully studied by members of the U. S. Geological Survey, and briefly stated is as follows: The district is composed of intrusive serpentine, bounded on the north and south by slate. Dikes of more recent volcanic rocks are numerous. Most of the veins run nearly east and west with the formation, and are generally found in the serpentine. The ores are free milling and concentrating. Some of the slips or ledges where the veins intersect have all the characteristics of regular pocket veins, and gold is found at the point of intersection. Other veins carry their enriched portion along lines of crushing. None of the veins are regular in width throughout their course, except where they occur along lines of crushing. It is probable that the gold was first deposited in the veins with the sulphides but was afterwards changed through a process of leaching into free gold. The gouge along the vein walls is usually talc, very seldom clay, and considerable gold is sometimes found in the talc, having been carried there in solution. Many of the miners have had the erroneous idea that all the green talc must necessarily carry gold. Along the line of enrichment it does, but not throughout the entire vein. The ores are of a good grade, many of them over ten dollars per ton and going as high as one thousand dollars per ton.

Most of the development work has been done at Blewett,

where the Chelan Mining Company has a twenty stamp mill on the banks of Peshastin creek. The history of this camp is similar to that of many which dot the eastern slope of the Cascade and Sierra Nevada mountains, and in a few words is a history of mining instead of mines. The first discoveries in the district were placer. The rich oxidized ores exposed over the surface of the hills above the creeks were worked in arrastras, and the mines gophered. No attempt was made to work the mines underground until 1874.

The principal work has been done in the ledges on the properties of the Chelan, Eleanor, and Peshastin Mining Companies. The total estimated output of the camp is $1,500,000 and these ledges contributed a considerable portion of this.

The lack of correct knowledge or experience in the character of the formation has resulted in the sinking of a hundred or more holes and cuts where ores have been extracted, and no further effort made to follow the line of enrichment. The amount of good ore that the surface has furnished has seldom been equalled by any camp along the range. Mining operations are not expensive, for shafts and tunnels can be driven for about five dollars per foot with hand labor. No trouble from water is experienced in sinking shafts. Few camps have so little controversy over boundaries as Peshastin mining district. The original corners are well understood and respected.

Eureka.— This mine is on Peshastin creek, about a quarter of a mile south of Blewett. The vein of ore varies from twelve to eighteen inches in width, has a strike east and west, and a dip to the south. The mine belongs to the Phœnix Mining and Milling Company, but all the work has been done by leasers, who have kept no records of the amount shipped, so that it is not possible at this time to state how much ore has been extracted, or form any estimate of its total value. Much of the ore assays in gold as high as thirty dollars to the ton. The property was first opened up twenty-one or twenty-two years ago, and up to the present time about $3,500 has been expended in development work, represented by about 600 feet of underground workings.

Tip Top.— The eastern extension of the Eureka mine is known as the Tip Top, and was opened up about the same time.

A large amount of ore was taken out in early days, estimated in value at about ten thousand dollars. The vein here is about two and a half feet thick and dips northward, with an east and west strike. About five hundred or six hundred feet of tunne has been driven, involving an outlay of about $4,000. The ore that is mined averages about twenty-five dollars to the ton in gold, and is treated by means of an arrastra, which is supplied with water by a ditch five hundred feet long.

Lucky Queen.—This mine is on the east side of Peshastin creek about a quarter of a mile north of Blewett, and was first opened up in 1894. There is one principal vein with a number of intersecting veins, and all stand nearly perpendicular. The ore is very pockety. About twenty tons have been sold to date, having a total value of about one thousand dollars. Two tunnels having a combined length of seven hundred feet, have been driven at an expense of about $3,500.

Culver.—The Chelan Mining and Milling Company has a group of five claims extending along Thompson gulch, from a point two thousand feet west of Blewett, and adjoining the Peshastin mine. This is an old property, having been first opened up in 1882, and since that time about three hundred thousand dollars worth of ore has been taken out. The vein varies in width from four to fifteen feet. It strikes east and west and dips to the southward. All the values are in gold, and the ore assays from five dollars to five hundred dollars per ton. There has been about four thousand feet of underground development work done, including tunnels, stopes, etc. The company has erected a twenty-stamp mill, and an aerial tram for handling and treating the ores. Steam power is employed. The total amount expended in all kinds of development work is estimated at one hundred and fifty thousand dollars.

Peshastin.—The Peshastin mine is in the town of Blewett. It is one of the oldest properties in the camp, having been first opened in 1874. The vein is from four to twenty feet wide, and like all other veins in the camp, has an east and west strike. It dips to the southward. Fifteen hundred feet of underground work has been done, representing an outlay of about eight thousand dollars. Four thousand tons of ore have been mined, hav ing an average gold value of $15 per ton.

Olden.—The property belonging to Mr. John Olden, is located west of the Black Jack mine, and immediately south of the Peshastin. It is an old property, having been opened up about twenty-one years ago. There are two veins varying in width from one to six feet, dipping north, and with an east and west strike. All the values are in gold. Three hundred and fifty feet of underground development has been done. Up to the present time the total output is five hundred tons of ore, having a value of twenty-five hundred dollars. The ore is treated in an arrastra operated by water power. The estimated cost of all development work done is fifteen hundred dollars.

Pole Pick.—This mine is on the north slope of Thompson gulch about half a mile west of Blewett. It was opened up in 1884 and since that time has produced eight thousand tons of ore, having a total value of about sixty-four thousand dollars. There are three veins varying from one to four feet in width. The strike is east and west and the dip is to the northward. The values are in gold and silver, with a little lead. There are about two thousand feet of underground work, representing an expenditure of twelve thousand dollars.

Golden Eagle.—This property includes three locations on the west side of Peshastin creek just north of Blewett. There are two veins on the property, each having a width of about three feet. The strike is east and west and the dip north. Like most of the other mines in the district the ore is very pockety, ranging in value from fourteen dollars to sixty dollars per ton. The owners have expended about seven hundred dollars in development work, and now have a tunnel two hundred feet in length. They have about one hundred tons of ore on the dump. All the values are in gold.

Ivanhoe.—The Ivanhoe mine lies north of the Culver at the head of Thompson gulch, about half a mile west of Blewett. It is an old mine, having been first opened up eighteen or nineteen years ago, but has never been worked very extensively. About five hundred feet of underground work has been done, and twenty-five hundred dollars have been spent in development work. The vein is six feet wide and carries gold and silver with an average assay value of four dollars and a half per ton. The vein is perpendicular and has an east and west strike.

Black Jack.—This mine is on Peshastin creek above Blewett. It was opened up about the same time as the Eureka, or about 1880. Nine hundred feet of tunnel have been driven on the property at an estimated cost of five thousand dollars. Three thousand tons of ore have been taken out with an average gold value of ten dollars per ton. The vein is from two to four feet wide, and has an east and west strike, dipping to the southward.

SNOHOMISH COUNTY.

Snohomish county lies between the counties of Skagit and King on the north and south respectively, and extends from the summit of the Cascades westward to Puget Sound. Like the counties to the northward and southward of it, Snohomish has a low alluvial plain along the coast, which gives way in turn to low hills, foot-hills of the mountains, and finally to very high mountains as one travels eastward.

The eastern part of Snohomish county, embracing about two-thirds of its area, may be regarded as mineral bearing. The rocks found here are of the varieties typical of the northern Cascades, viz.: granite, diorite, slate, gneiss, schist, crystalline limestone, etc. At several points valuable veins of ore have been discovered, notably about Darrington, Silverton, Monte Cristo, and Index. The ores found in these districts are practically all of the sulphide type, making treatment by smelter methods a necessity. An easy method of transportation from the mines to the smelter is therefore required, and in this the mining properties of Snohomish county are favored much better as a rule than is the case elsewhere in Washington. Three lines of railway extend from tide-water into the heart of the mountains and into the midst of the mining districts, viz.: a branch line of the Northern Pacific to Darrington, in the northern part of the county; the Everett & Monte Cristo to the town of Monte Cristo, in the central part of the county; and the Great Northern to Index, in the southern part of the county. Of these rail-

ways the first and second were constructed primarily for the purpose of hauling ore from the mines, while the third is of course a part of a great overland system.

DARRINGTON DISTRICT.

By D. A. Lyon.

Darrington district is situated in the northeast corner of Snohomish county. Although it is unorganized, yet its boundaries may be considered to be the Skagit county line on the north, the Stilaguamish district on the south, and the summit of the Cascades on the east. The district is drained by the Sauk river and its tributaries. The principal town of the district, Darrington, is situated about 25 miles above the mouth of the Sauk. The district is one of the most accessible in the state. During the past year the Northern Pacific railway extended a branch line from Arlington to Darrington. There are also several good wagon roads leading into the district. Not only is the district well located as regards accessibility, but because of the low altitude the mining industry is not handicapped by the deep snows, as is the case in the higher Cascades.

Although more or less development work has been going on in the Darrington district for some years, none of the mines have ever been regular shippers. This has been due partly to the fact that capital has been wanting to develop the properties sufficiently, and also because there has been no way of getting the ores treated after they have been taken out, for the ores of the district are smelting ores. Now that the district has been entered by a railroad, it will be possible to interest capital in the mines and property holders now feel that the future of the district is assured. Most of the mines of the district are all at a higher elevation than Darrington, and as the district is developed it seems quite likely that a system of aerial tramways will be used for delivering the ores from the mines to Darrington, either for treatment at that point, or to be loaded and shipped to smelters at Tacoma and Everett. One of the largest property holders of the district informed the writer that ore can be mined and delivered at Darrington for $3.75 per ton. The rate on ore by rail from Darrington to Everett is $2, or to Tacoma $2.50 per ton. Thus, ore can be mined, freighted and smelted for about $10.75 per ton. As the ores of the district run from

$16 to $84 in value per ton, it would seem as if mining could be carried on in this district at a profit.

Darrington is not only a mining center, but it is situated also in the heart of a very extensive timber district, and in the near-by river valleys there are also large areas of agricultural land.

As to the rock formations of the district, we find in at least two places the same kind of fine grained black slate which is found along Ruby creek and on Slate creek. In the first of these places the slate is found on each side of Sauk river for a distance of about ten miles, and below the mouth of Whitechuck creek. The second locality is found on the west bank of the Sauk, beginning about three miles below Darrington, and extending for four miles. There are also large bodies of serpentine in the district. Most of the ore bodies have slate for a hanging wall and porphyry for a foot wall. The following are some of the more important properties of the district:

Burns.—The Burns group consists of seven claims which are situated on the west side of Gold mountain. The ore body has been exposed for a distance of 100 feet, and is shown to have an average width of 4½ feet. The ledge can be traced as far as the Sauk river, where it has an outcrop of 6 inches. It has an east and west trend and a dip that is nearly vertical.

Blue Bird.—The Blue Bird group of claims is owned by S. S. Gardiner and others of Everett. Between two and three hundred feet of tunneling has been done on this property, and 100 tons of good ore taken out which assays about $33 per ton. The vein of ore has an average width of eight feet.

Elwell-Darrington.—The property of the Elwell-Darrington Mining Company is on the east side of Gold mountain, and is located on an extension of the Burns group. The principal ledge is from 7 to 8 feet wide, with a pay streak varying from 2 to 3 feet in width.

Harley.—The Harley group consists of eight claims, which are situated about the middle of Gold mountain, and owned by Chas. Burns. The vein of ore is 4 feet wide and outcrops for about 150 feet. It carries mostly gold values, and assays $42 or $43 per ton.

Hunter and White Gander.—The Hunter and White Gander group, made up of six claims on the west side of Jumbo mountain, is owned by Burns and Neste. The development work consists of three open cuts and one 50-foot tunnel on the Hunter, and one 15-foot tunnel and two open cuts on the White Gander. The average assay value of the ore is between $15 and $20 per ton.

Molly.—This group is also located on Jumbo mountain, and is owned by Neste and others. The development work on these claims consists of two tunnels, one of which is about 170 feet in length, and another 50 feet in length. The average assay value of the ore is about $15 per ton, of which one half is in gold and the remainder in silver and copper. The same proportion holds good with the other ores of Jumbo mountain.

Sloman.—The property is situated on the north side of White Horse mountain. The ledge is about five foot wide, and a mill test made on the ore gave it a value of $33 per ton. The property has been developed to the extent of two tunnels of 50 feet each.

There are many other properties in the Darrington district which have been located for some time, and upon which a considerable amount of development work has been done. There is no reliable data at hand concerning these, and for that reason they can not be mentioned in this report.

STILAGUAMISH DISTRICT.

BY WM. S. THYNG.

The Stilaguamish mining district, of which the center is Silverton, lies upon both sides of the Stilaguamish river, in very nearly the geographical center of Snohomish county. Silverton is reached from Seattle, via Everett, by the Everett & Monte Cristo Railway, which follows the valley of the Stilaguamish river. The town of Silverton, located in the river valley, lies at an altitude of about 1,500 feet above sea level, while on both sides the mountains rise to a height of from 3,000 to 5,000 feet above sea level, with the characteristic rough contours of the Cascades.

Previous to 1897 a very large number of claims had been located in this district, both north and south of the river, and

many of the properties so located had already given great promise as future producers, and considerable ore had been shipped, when in November, 1897, the excessively high water in the Stilaguamish, caused by the melting snows above caused a number of very bad washouts along the line of the Everett & Monte Cristo Railway, putting a stop for the time being to all mining operations along the line. This shutdown, as it may be termed, of all the mines of Silverton, continued until early in the season of 1901, when the railroad having been extensively repaired, and even rebuilt at many points, mining operations were again resumed. The repairs made upon the roadbed were of so substantial a character, and so well protected is the road, that no future trouble is looked for from high water in the river.

The general direction of the Stilaguamish, as it passes through this district, is east and west, which is also the general trend of the mountains on both sides of the river. From the river valley at Silverton wagon roads and trails, principally the latter, radiate in all directions to the different mining properties located in the surrounding mountains. A broad mineral belt, averaging perhaps ten or twelve miles in width, and which contains most of the important ledges of the district, extends nearly north and south at this point. The individual veins or ledges extend in a general east and west direction, those lying to the north of the river showing a general tendency to strike a little to the north of east, while those on the south side of the river maintain a general strike to the south of east. The veins thus show, apparently, a tendency to converge as the river is followed downward or westward.

It seems altogether probable that the mineral belt described is the same which includes Darrington on the north and Index on the south, although the ores of the latter locality can hardly be called similar. The underlying or fundamental rock of the district is undoubtedly granite, with certain of the sedimentary rocks superimposed above. Following down the valley of the Stilaguamish, from above its junction with Palmer creek to a point several miles below Silverton are found a series of terminal moraines, showing clearly the glacial retreat up the river valley. At some points these moraines immediately overlie the granite formation.

While many true fissure veins are found in the district, still

a large number of ledges occur at contacts of granite and diorite.· The characteristic ore is chalcopyrite, which in the majority of cases carries the gold values. The chief values found in all the ore thus far mined lie in copper, gold aud silver, which last usually occurs with galena, found in a greater or less amount in most of the ores. Pyrite, arsenopyrite (mispickel) and pyrrhotite are very frequently found associated with the more common chalcopyrite; zinc blende (sphalerite) is also frequently met with, and most commonly occurs associated with the galena. Small quantities of ruby silver, chiefly antimonial (pyrargyrite), are occasionally found, notably in the ore of the Forty-five mine.

The topography of the country is admirably adapted to economical mining, many of the mountain slopes being so steep that considerable depth may be obtained with a comparatively small amount of tunnel work. As but one of the mines of the district, the Forty-five, is or has been a regular shipper of ore, Silverton may fairly be considered as in its infancy as regards production, and it may readily be seen that an enormous amount of ore lies in the surrounding mountains, ready to be mined and shipped without the sinking of a single shaft. While the smaller creeks which drain the district and empty into the river from the sides, can not all be depended upon for a steady flow at all seasons, and hence do not offer the best facilities for water power, still outside of the question of power, they should furnish ample water for each individual camp.

The district has not by any means been thoroughly prospected at all points, although the ground has been fairly well covered within a radius of four or five miles from Silverton. Most of the region is heavily timbered, which, together with the thick surface soil at many points, makes thorough prospecting a difficult matter. Mr. R. H. Stretch, who has made a careful study of the geology of the district, is authority for the statement that a few miles east of Silverton, the overlying sedimentary rocks contain thin beds of coal, apparently semi-bituminous, which in all probability belong to the same age as the coal fields of Hamilton, in Skagit county, but lying on the eastern slope of a broad anticline along the crest of which the mineral zone has been developed. Mr. Stretch further believes that it is not unlikely that the general strike of one system of lodes—the northwest—is in

some way connected with the southeast course of Deer creek, which is continued in the bed of the Stilaguamish river from the mouth of Deer creek to the summit of Barlow pass. To this system belong such mines as the Forty-five and the Bonanza Queen, to the south and north of Silverton respectively, the fissure in each case having been traced through many contiguous claims.

Ore was first discovered in this region in the summer of 1891, when the Hoodoo, Independent, Anacortes and Bonanza Queen ledges were found and located. The first name of the camp was Independence, but in August, 1891, the name Silverton was adopted, and a town site was established the following winter. The railroad was built in 1892–3.

Forty-Five.—This is the only property in the district which has shipped any large amount of ore at the present time. It is owned and managed by the Forty-five Consolidated Mining Company, of which Mr. L. A. Dyer is president and Mr. N. B. Jones, superintendent; the offices of the company are in Seattle. The company owns six claims upon what is known as the Deu Pree lode, and located on an air line about two miles southeast of Silverton. The mine is reached from the town by pack trail, which passes through Marble pass at an altitude of 4,190 feet; the mine is also reached by wagon road from Sultan, a point to the southwest on the line of the Great Northern Railway.

The six claims owned by the company are the Herb, Norm, Mountain Ram, Magus, Deu Pree and Hard to Beat. The ore body is a fissure vein cutting through diorite, and strikes a few degrees to the north of west, dipping south at an average angle of 80 degrees. The average width of the ledge is not far from six feet, and the mineralization is quite uniform, there being no distinct pay streaks; the gangue material is largely quartz, much of it somewhat decomposed. Although the chief values are in silver and gold, the ore is very base, carrying an average of four per cent. of galena, and considerable amounts of zinc blende and iron pyrites, besides some chalcopyrite and mispickel; gray copper ore (tetrahedrite) is also found, sometimes in notable quantities. The greatest values in both of the precious metals are found in the galena, although some of the silver is associated with the pyrite; near the surface, considerable ruby silver,

mostly of the antimonial variety (pyrargyrite), is encountered, often in large enough quantities to form handsome specimens.

The main workings of the mine are located on the Magus claim, about 4,000 feet above the sea level. Here the main tunnel, No. 2, has been run in 232 feet to the vein, along which about 950 feet of drifting has been done; from this drift, a two-compartment shaft, 5 by 8 feet in cross-section, has been sunk a distance of 107 feet, and at the 75-foot level, 135 feet of drifting work has been done. From the main level, cross-cuts aggregating 150 feet have been run, chiefly to prospect for parallel ledges. On the Deu Pree claim, tunnel No. 1, the first one driven by the company, cuts the vein at a distance of 27 feet, and from that tunnel 100 feet of drifting has been done. About 175 feet of drifting has been done upon the Hard to Beat claim, the most easterly of the group. All drilling is done by hand, as, with the single exception of the Independent mine, no machine drills are used in the district.

The contours of the country, and present economic conditions, make it necessary to carry the ore by aerial tramway to Silverton, the nearest railroad point. A wire rope gravity tram of the Hallidie patent, brings the ore down the mountain side, a distance of 3,700 feet, to the headquarters camp, located at an altitude of about 3,000 feet. At this point the ore is roughly handpicked and transferred to a second tram, of the same patent, 13,200 feet long, which runs via Marble Pass (whose altitude is 4,190 feet), to a point upon the railroad about one-quarter of a mile below Silverton, and from whence the ore is shipped. As the two parts, or legs of this main tram, on each side of Marble pass, are too nearly equal to admit of its running by gravity alone, additional power is had from an electric motor placed at the headquarters station.

Previous to the building of this tram, in 1897, high grade ore was taken to Silverton by pack train, and shipped from that point. The tram was completed just as the washout occurred upon the railroad, but considerable high grade ore was still shipped while the railroad was out of service, by wagon road, to Sultan. This shipment by pack train and wagons involved the accumulation of considerable ore of lower grade at the mine and headquarters camp, and in August, 1901, it was estimated that about 15,000 tons of this lower or second grade ore was still on hand.

Little Chief.—About a mile and a half due south of the Forty-five No. 2 tunnel is found the Little Chief property, owned by the Stilaguamish and Sultan Mining Company, of which Mr. J. W. Clise, of the Clise Investment Company, Seattle, is vice-president and general manager. Upon this property, which lies on the west side of Little Chief peak, about 300 feet of tunneling and 100 feet of drifting has been done, together with some 60 feet of cross-cuts. The company has also done considerable prospecting with diamond drill, but the mine has thus far never been a producer. The ore is low grade, with the chief values in gold and copper.

Independent.—Of the other properties upon the south side of the river, the Independent probably comes second in importance at the present time, to the Forty-five. This mine is located less than a mile to the southeast of Silverton, and of all the properties of the district, is probably the easiest of access. It is owned and operated by the Copper-Independent Consolidated Mining Company, of which Mr. M. D. Little, of Boston, Mass., is president, and Mr. Arthur W. Hawks, of Snohomish, general manager.

The ore body is a fissure vein in granite, and strikes very nearly north and south, with a steep dip. The values are in gold, associated chiefly with arsenopyrite, although considerable amounts of iron pyrite are found. The mineralization is quite uniform throughout the ledge, which is wide and has pronounced walls. The ore is of such character as to require concentration before shipping. The main opening consists of a drift about 500 feet long, from which a raise has been pushed up 120 feet to a short tunnel or drift above. That the vein matter upon the ledge is very soft is shown by the fact that it has suffered a large amount of erosion between the walls, forming a steep chasm, which has become the bed of a small water course. A three-drill air compressor was installed at the mine during the summer of 1901, and preparations made to put out ore for shipment, but since that time it has been impossible to obtain from the officers of the company any information as to advancement in development. One car load of picked ore has been shipped to the smelter at Everett.

Imperial.—The Imperial mine, owned and operated by the Imperial Mining Company, lies about one and one-half miles

east of Silverton. The president of the company is Mr. James E. Deu Pree, of Marysville, and Mr. M. Swinnerton, of Silverton, is superintendent. The company owns eleven claims covering three ledges, the most important of the claims being the Anacortes and the Mountain View. The main vein is in a contact of diorite and conglomerate. The chief values of the ore are in copper and silver, with some small amounts of gold. A total of about 400 feet of development work has been done, the main tunnel having an altitude of 2,500 feet.

Bonanza Queen.— This group of eight claims is located about one mile due north of Silverton, and on the west side of Deer creek. The property is still in the hands of the original locators, who are represented in Silverton by Mr. A. Sutherland. The claims cover four distinct ledges, of which the most important are the Bonanza Queen and the Oregon, running nearly parallel and side by side. It strikes southeast by south, and stands nearly vertical. The values are chiefly in gold and copper, which occur associated with mispickel. The vein is wide, and the mineralization, forming the pay streak, has taken place chiefly along the foot wall. A total of about 1,200 feet of development work, mostly drifting, has been done upon the property; the very abrupt slopes which are met with, particularly upon the most northerly claims, offering unusual facilities for cheap mining. The average altitude of this group is 2,700 feet.

St. Louis.— The St. Louis mine is on a ledge which is cut by Deer creek, about three miles north of Silverton. It is reached from town by a four-mile wagon road, following up Deer creek. The ledge is mostly of high grade ore but is very narrow, ranging usually from about 18 to 36 inches. The property has been opened by two drifts, connected by a winze, some of the work having been done by power drills. The main drift is about 600 feet in length, and shows good continuity of ore, which is mostly chalcopyrite, with copper values running about 20 per cent. Considerable silver and some gold is found associated with the ore. At the present time very little besides assessment work is being done upon the property. Some small shipments have been made.

Helena.— This group of claims, owned by the Deer Creek Gold and Copper Mining Company, is located some two miles

north of the St. Louis upon the divide between Deer creek and Clear creek. All of this divide is taken up in claims, which cover two systems of veins. The wagon road which leads past the St. Louis reaches to the foot of the divide, but in order that ore may be shipped in any quantity, a tram of some form will be necessary to bring it down from the mine. The granite formation is exposed for several hundred feet along the side of the mountain, and shows a ledge of great width carrying low grade ore. The main tunnel, which is located some 800 feet from the summit, is 124 feet long, and from it 125 feet of drifting has been done. Another tunnel has been started about 1,000 feet below to tap the main ledge. A number of small shipments aggregating about 150 tons were made before the railroad washout to the smelter at Everett, but at the present time nothing beyond assessment work is being done.

Another group of claims near by and well worthy of mention is that of the Four Brothers, owned by the Copper-Independent Consolidated Mining Company. About 130 feet of development work has been done upon this property, which lies west of the Helena group.

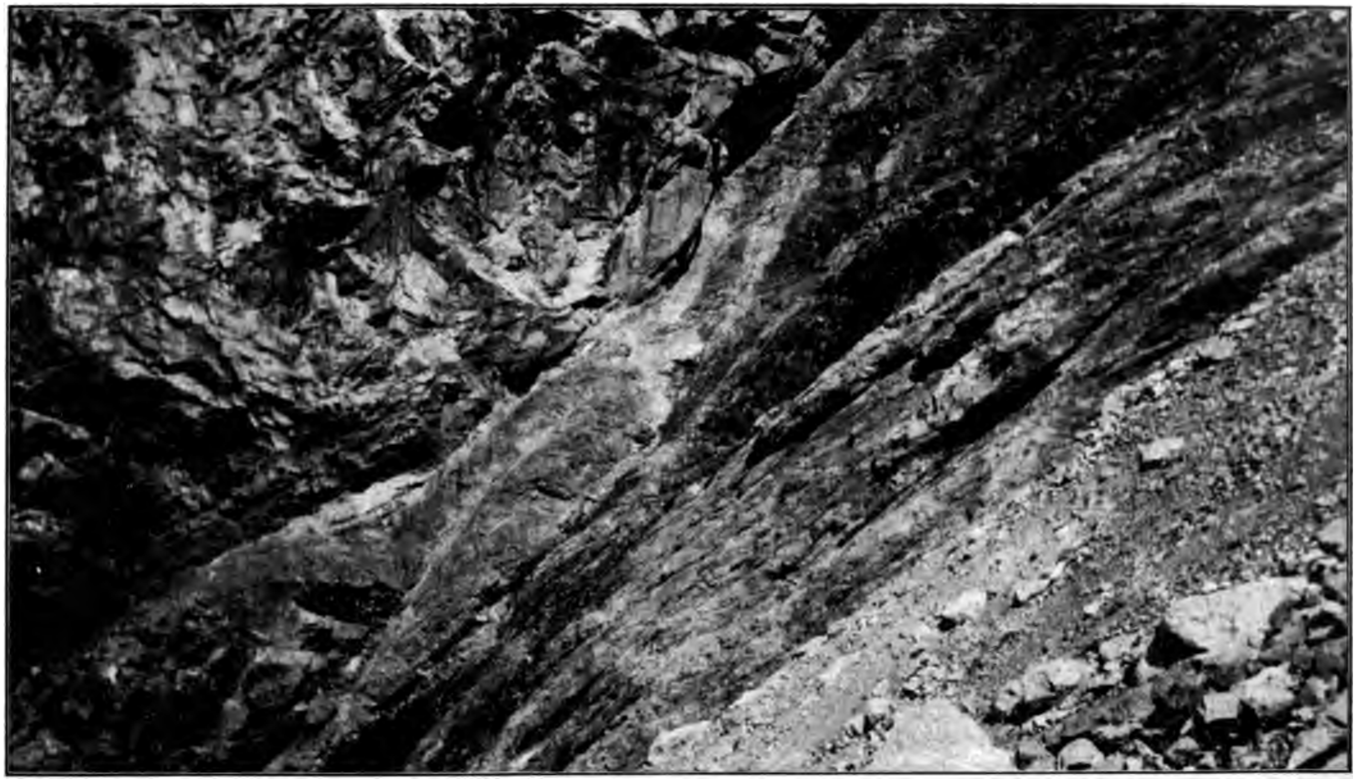
Although, outside of the Forty-five mine, no ore of any consequence was shipped from this district during the past season, 1901, a very large amount of assessment work and considerable further development was done, notably upon the Hoodoo group south of the river, and owned by the Stilaguamish and Sultan Mining Company, the Fraction, New Seattle, Cleveland and others.

Silverton is but 48 miles by rail from the Everett smelter, which fact in itself should be of the greatest value in the future successful development of the district.

MONTE CRISTO DISTRICT.

BY WM. S. THYNG.

This district is located in the eastern part of Snohomish county, about twelve miles southeast of Silverton. The town of Monte Cristo, which forms the terminus of the Everett & Monte Cristo Railway, is reached from Seattle via that road, making connection with the Northern Pacific branch line at Hartford Junction, or with the Great Northern Railway at Everett. Monte Cristo is located in the valley of the Sauk river, just



OUTCROP OF INDEPENDENCE LEDGE, MONTE CRISTO.

below its source; the town occupies an immense natural basin, with precipitous mountains rising upon all sides, which are cut in many places by steep gulches.

The first claim staked in the district was the Independence of 1776, located on the 4th of July, 1889. This claim is situated upon the east side of what is now known as Seventy-six gulch. The ledge has a most pronounced outcrop which can be traced a long distance up the steep side of the gulch, until it is finally lost under a large glacier. The ore body at the outcrop is composed largely of galena. It has been opened at several points by short drifts and open cuts, but no ore has been shipped and no work worthy of mention has been done upon it for several years. This is now one of the many properties in the district owned by Mr. John D. Rockefeller and his business associates.

All of the properties of this district, like those tributary to Silverton, underwent an enforced shut-down during the two years following the washout of the Everett & Monte Cristo Railway, which occurred in November 1897. During this period the only means of communication with the outside world was over the dismantled roadbed of the railway which follows the valley of the Stilaguamish river. Since the repairing and rebuilding of the railway, while this dirtrict has not enjoyed the marked revival of interest which has taken place in Silverton, it has nevertheless resumed its place as a large producer of ore. The output has been, however, almost entirely from the property of the Monte Cristo Mining and Concentration Company, which is, therefore, at the present day as well as in the past, the chief producer.

Monte Cristo. — The Monte Cristo mine, operated by the above mentioned company, of which the president and chief stockholder is Mr. John D. Rockefeller, and the superintendent Mr. William E. Sutton, is now operating three claims, viz.: the Pride of the Woods, the Pride of the Mountains, and the Eighty-nine. These are three of the fourteen claims upon which the mine is located. The company owns a total of thirty-five claims in the district. In the Monte Cristo mine about 12,000 feet of tunnel and cross-cut work have been done, besides a large amount of stoping. The principal vein, which has been formed in a fissure in diorite, strikes a little north of east with a dip ranging from 55 degrees to 70 degrees to the northwest. The values run

chiefly in gold and silver, although some lead is saved in smelting. The milling ore extracted from the mine averages $6 per ton in value, of which about $4 is in gold. This ore is concentrated in the company's mill, located in the town of Monte Cristo. In the concentration the ore is brought down from 3 or 3½ tons to 1 ton. The mine is located due east of the town, all of the ore being transported to the mill by two wire rope trams, of the Bleichert patent, one 3,600 feet and the other 6,250 feet in length. The mine during the past summer (1901) was producing ore at the rate of 3,500 tons per month, so that about 1,000 tons of concentrates were shipped monthly. While working, with the exception of the first two years of its history, the mine has produced an average of 39,000 tons of milling ore yearly. All of the ore which is mined is crushed and washed, the product containing an average of but ten per cent. of gangue matter. The loss in concentrating is stated to vary from 18 to 30 per cent. according to the degree of mineralization of the ore treated. All of the concentrates are shipped to the smelter at Everett.

During the summer of 1901 the Monte Cristo was the only mine in the district that was shipping ore. Other properties were either lying idle or else undergoing little besides assessment work.

O. and B.—Among the other properties which have shipped ore from this district in times past the O. and B. mine should be mentioned as perhaps the most important. This mine was operated until a short time before the railroad washout, when operations ceased, it is understood, on account of certain internal troubles among the owners. The mine is located about one-half mile south of Monte Cristo and has an elevation of some 1,200 feet above the railroad. The ore occurs as a fissure vein in diorite. The outcrop is exceedingly well defined and with the present development shows good continuity of vein. The ore consists mostly of pyrite and arsenopyrite (mispickel) with some galena and zinc blende in a gangue of quartzite. The development to date consists of two drifts about 70 feet apart, vertically, and aggregating about 600 feet in length. Considerable stoping has also been done, mostly from the lower, or main drift. The ore was hand-sorted at the mine and brought down to the railroad by means of a wire rope gravity tram. The tram has been removed since the shut-down of the mine. About twelve car

loads of ore in all were shipped from this mine to the smelter at Everett.

The ore bodies in the district exist largely as lenticular masses with very little uniformity in strike and dip. It has been found in the development of a number of the properties, that on the flatter pitches in these lenses the mineralization is heavier than where the dip is steeper, but that at the same time the gangue minerals are quite largely disintegrated. At all depths so far reached, the greatest of which exceeds 1,200 feet from the surface, sphalerite (zinc blende) is encountered in quantities averaging about five per cent. of the total mineralization and carrying small amounts of disseminated galena. The pure galena which is found in these veins rarely occurs, however, at a greater depth than 150 feet and then usually accompanied by chalcopyrite in varying quantities. The arsenopyrite or mispickel, which carries the greatest amount of gold values, is found pure at all depths and rarely changes its value in gold; the iron pyrite undoubtedly decreases in value with depth, and in many instances is altered, or replaced by pyrrhotite. Realgar is found at all depths and runs downward from the surface in distinct and narrow chimneys.

The ore shoots themselves, so far as have been shown by the dovelopment work in the Monte Cristo mine, have never been less than 200 feet long (measured along the strike of the vein), and over 700 feet in depth. The ore shoots or pay streaks are readily distinguished on the eroded surface of the outcrop as well as under ground. The arsenopyrite, or white iron as it is locally called, carries values as high as 2½ ounces of gold and 6 or 7 ounces of silver per ton of ore.

Thus far in the development work of the district no faulting to any extent in the ore bodies has been discovered.

SILVER CREEK DISTRICT.

BY WM. S. THYNG.

This district, as the southern extension of the Monte Cristo mineral belt, forms practically a connecting link between the Monte Cristo district on the north, and the Index district on the south. Silver creek has its source in Silver lake on the divide about one and one-half miles southwest of Monte Cristo, and

joins the north fork of the Skykomish river at Galena, nine miles to the southward.

The mines in the district are properly tributary to Index, from which place an excellent wagon road, built and maintained by Snohomish county, follows up the north fork of the Skykomish river ten miles to Galena, the most southerly point of the district. From Galena, all of the different properties located further up on both sides of the creek, are reached by trail. The district received its name from the deposits of silver-lead ore first found in the neighborhood of Galena. As the country above was further prospected and developed, however, large bodies of copper and iron carrying gold were found, so that when the district becomes a producer, the ores shipped will be of a varied character. The district was one of the first discovered in the Cascades, and although it contains a very great number of properties, many of them high grade, the lack of transportation facilities thus far has been the cause of a disproportionately small amount of development work being done. A railroad built from Index into the district would undoubtedly awake the very greatest activity in mining work, and there are a considerable number of properties which could thus at once be placed upon a paying basis.

The country rock of the district is mainly granite, less of the overlying sedimentary rocks being found than at Silverton to the northward. The granite outcrops at a number of points along the entire length of Silver creek. The ore bodies are mostly true fissure veins, which have a general trend a little to the south of east. The ledges or veins are cut and faulted to some extent by probably a later series of fissures, which appear to have a general direction or strike of northeast and southwest. It should be remembered that the mineralization at the head of Silver creek, in the upper part of the district, is principally in copper and iron, the latter appearing chiefly as arsenopyrite, carrying the greater values in gold and silver; the lower part of the district, about and immediately above Galena, contains a large amount of silver-lead ore, although considerable chalcopyrite is still found here carrying some gold but taking second place.

Bonanza.—Possibly the most notable property in the district is that of the Bonanza Mining and Smelting Company, of which

Mr. Peter Chiodo, address Index, Washington, is president and general manager. This property consists of twelve claims, located on the west side of Silver creek, one mile above Mineral city, or about midway between Galena and Monte Cristo. These twelve claims are the Louise, Edison, Rattler, White Rose, Emma, Monarch, Northern Light, Leo, Maggie, Jessie, Juno and Red Rose. Considerable parallelism is found in the ledges covered by these claims, the general strike being a little east of north. Up to August, 1901, the development work aggregated some 1,500 feet; a main crosscut tunnel has been run into the mountain, a distance of over 600 feet and has cut five wide ledges of 60, 40, 15, 10 and 10 feet respectively. At a point about 100 feet beyond its present face this crosscut tunnel is expected to reach the Edison ledge, supposed to be 50 feet wide. Besides this main tunnel a considerable number of prospect tunnels and open cuts have been driven to prove the continuation of the deposits, all on a higher level. The ore is arsenopyrite and chalcopyrite, the former carrying gold. All five ledges contain concentrating ore at many points, which extends from wall to wall. The value of the ore is mostly in gold, which as before mentioned is found chiefly associated with the arsenopyrite. The value of the ore varies from $10 to $15 per ton. The veins are true fissures and the country rock is granite. (C. R. Redding, Index.)

Copper Chief.—The Copper Chief claims, four in number, operated by the Copper Chief Mining Company, are all located upon a ledge extending from a point on the west bank of Silver creek about midway between Galena and Mineral City for 6,000 feet up the mountain side. The ledge strikes about east and west, with a nearly vertical dip. The property was opened up in June, 1899, since which time about $5,000 has been spent in development work. A total of 320 feet of drifting has opened up considerable ore, of which the assays average $24 in gold, silver and copper. The vein is eight feet in width and the ore consists of chalcopyrite, galena and arsenoyyrite, which last carries most of the gold values.

Ontario.—The Ontario group of five claims, lying immediately south of the Copper Chief group, is located upon a ledge which is very nearly parallel to that of the Copper Chief. Work

was begun upon this property in March, 1900. A number of drifts have been run upon the vein at different levels, aggregating in length a little over 400 feet, and it is estimated that about 100 tons of ore are at present on the dump. The ledge is about six feet wide, and dips steeply to the north. The ore is chiefly galena, carrying paying quantities of lead and running high in silver. Some value in gold is also found, but associated chiefly with iron pyrite, which occurs in small quantities. The country rock of this property and also of the Copper Chief is diorite.

During the summer of 1901 a considerable amount of development work was done in the district over and above the necessary assessment work. As a result of a number of important properties having recently changed ownership, the season was one of considerable activity.

INDEX DISTRICT.

BY WM. S. THYNG.

The Index district, of which the town of Index forms the economical center and shipping point, is located in the southern part of Snohomish county. The town is situated at the junction of the north and south forks of the Skykomish river, and may be said to be practically surrounded by its tributary mining properties, although most of the more notable ones lie upon the eastern side; the property of the Bunker Hill and Sullivan Copper Mining company, which lies five miles to the northwest, is the most noteworthy exception to the last statement. Index lies upon the main line of the Great Northern Railway, 69 miles from Seattle, and but from 36 miles from the Everett smelter. The excellent transportation facilities thus enjoyed by the district gives it a signal advantage over the greater number of the mining districts in the Cascades, and indeed, over the greater proportion of the mines in the whole State of Washington.

The Index district is here considered as including all of the properties located along and on both sides of the north fork of the Skykomish river, both below and above Galena. The Silver Creek district, tributary to Index, and described elsewhere, is often considered as including all of the mines between Monte Cristo and Index, located along the courses of both Silver creek and the north fork of the Skykomish, the former stream joining

the latter at Galena, ten miles above Index. On account of the geographical features, however, as well as of the marked difference in the character of the ores above and below Galena, the first mentioned division is thought to be more logical and proper.

The mines of the district are located mostly at some little distance from the town, the nearest property of importance being that of the Index Mining company, to be described later. Some of the mines, notably the Ethel and the Sunset, are provided with excellent means of ore transportation to Index, by wagon road and surface tram. The Copper Bell, the property of the Bunker Hill and Sullivan Copper Mining company, has its own connection with the railway, at a point about five miles west of the station at Index. Thus far most of the other properties are reached only by trail, but a considerable number are so located that connection might easily be had with the nearest point upon the railway by means of aerial or wire rope tramways.

The fundamental formation of the district is granite, which is in places crossed by dykes of trap, and at other points is overlaid with what appears to be slate, probably metamorphosed shale, and which is considerably altered and softened at the surface. Small amounts of impure limestone are also found at certain points. So far as development has progressed there appears to be but little uniformity in the trend or direction of the important ore bodies, but by far the greater part of the ledges appear to be fissure veins, cutting the granite formation. The typical ores are chalcopyrite and bornite, the latter being generally found in greater proportion as depth is attained. Along with bornite, in many instances, a considerable amount of chalcocite (copper glance) is found, and in some few instances small quantities of tetrahedrite (gray copper ore) are met with. Silver is found in many instances in connection with the copper and iron and often in considerable amounts; gold is not so usual, however, and is rarely high in value, although in this district some veins have been discovered of what may be fairly considered true gold ore; this gold ore is claimed to be free-milling, although the properties have never been worked. Index is, therefore, to be properly considered a copper mining district, and as such it is, and always has been, exploited.

Ethel.—By reason of its great activity during the past season, that of 1901, and the amount of surface development accom-

plished, the property of the Ethel Copper Mining Company should probably receive first mention in this district. Mr. G. A. Pounder, Seattle, Washington, is president of the company, and Mr. G. C. Clark, Everett, is superintendent. The property is located five and one-half miles northeast of Index, upon Excelsior creek, and but a few hundred feet above the junction of the latter stream with the Skykomish. It is reached from the main county wagon road extending from Index to Galena, by its own wagon road, built mainly of puncheons; this road, which was built during the fall of 1900, at a cost of $2,000, is 2,500 feet long, and has an average and fairly uniform grade of 10 per cent. This road is built up to the headquarters camp, at which point a concentrating mill has just been erected, with a capacity of 100 tons per month. The mine property comprises a group of eight claims, five of which are at present being operated to a greater or less extent. The principal mine workings are located about 2,600 feet northwest of the millsite, or headquarters camp, and at an elevation of 600 feet above the same, and a surface tramway, part of which will operate by gravity, was built at the same time as the mill, for the purpose of bringing down the ore. The mine was opened in October, 1899, since which time a considerable amount of development has been done, the ore-body having been blocked out so that stoping could begin with the completion of the mill. Two main tunnels have been driven 175 feet apart vertically, to reach the vein; the lower tunnel is 460 feet in length, and from it something over 250 feet of drifting has been done upon the vein; a raise has also been pushed up from this drift, a distance of 75 feet; the upper tunnel reaches the vein at a point 213 feet from the surface, and from this tunnel drifting has been carried in both directions, aggregating 500 feet, with a rise 80 feet in height. Besides these two principal openings, about 600 feet of cross cuts have opened up the vein at a number of points. The main ore-body, so far as is shown by the developments to date, appears somewhat lenticular in shape, with an average width of about six feet. It is apparently a fissure vein, and strikes east and west with a vertical dip. The country rock is granite. The ore is chalcopyrite, bornite, and chalcocite (copper glance), the bornite being considerably in excess, particularly in the lower levels, or as depth is reached. The average copper contents of all ore mined are

about 4 per cent., and it has been found thus far that silver occurs in amounts averaging two ounces to each per cent. of copper in the ore. The gangue matter is essentially quartz, but at some points small amounts of calcite are found included in the vein matter. The elevation of the upper tunnel is 1,840 feet above sea level. During the summer of 1901, when a large amount of work was done in surface improvements and developments, about forty-five men were employed, of which number ten were working underground. The surface plant at the headquarters camp includes, besides the concentrating mill, a small air compressor, a very complete saw mill, and the necessary buildings for the accommodation of the men. It is estimated that about 5,000 tons of milling ore are now upon the dump, but no ore has at this date, August, 1901, been shipped.

Sunset.—The Sunset mine, owned and operated by the Sunset Copper Mining Company, is located about six miles northeast of Index on Trout creek. The property is reached from Index as follows: From a point immediately above the town, on the north fork of the Skykomish, the company has built a surface tram which follows up the river, along its east bank, four and nine-tenths miles, to the mouth of Trout creek; thence, crossing Trout creek a gravity surface tram, 1,300 feet long, runs up the side of the mountain; thence, a further surface tram, one mile long, leads to the mine. The property comprises eight claims, located upon three parallel ledges, which strike east and west, and dip steeply to the north. Up to the present time, only one of the three ledges has been developed to any extent. This ledge, which cuts the granite formation, varies in width from 3½ to 16 feet, but no figures of average width could be gained. It has been found that the percentage in copper contents is greatest in the swells or lenses. The ore is essentially chalcopyrite and bornite, the chalcopyrite only appearing upon the outcrop and in the workings near the surface, the bornite coming into evidence as greater depth is reached; the ore carries varying amounts of gold and silver, the percentage of gold being greater in the chalcopyrite, and that of silver in the bornite, rather a remarkable fact. The gangue matter is mostly quartz, showing some decomposition on the outcrop, but becoming very solid as depth is gained. The main tunnel, which is located at an elevation of 1,450 feet above sea level, struck the

vein at a depth of 200 feet, and from that point drifting was carried in both directions, aggregating about 500 feet, and a rise was made to the surface. From these workings about 150 tons of selected ore were shipped to the smelter during the summer of 1899. Besides the main opening just described, a number of short crosscuts, all at higher levels, have been made to the vein, besides some small open cuts.

Copper Bell.—This property, owned by the Bunker Hill and Sullivan Mining Company, is located five miles northwest of Index, and one-half mile from the Great Northern Railway. It consists of nine claims, of which but two, the Copper Bell and the Jumbo, have been developed. The two ledges represented by the developed claims lie parallel with a strike of north fifty-five degrees east. The angle of dip has not as yet been determined since no distinct walls have been found up to the present time, and development work has not as yet been pushed far enough in depth for any accurate measurements to be made. Copper occurs in both ledges in the form of chalcopyrite, which is stated by Mr. Eckerson, the superintendent, to average, so far, 8 per cent. in copper with $2 in silver to the ton, and a trace of gold.

The total underground development to date is about 1,000 feet, most of this work having been done upon the Copper Bell claim. The work upon the Jumbo claim, up to August, 1901, consisted of 90 feet of tunnel, 35 feet of crosscut and 20 feet of shaft. A four-drill, steam-driven, Leyner compressor was installed at the Copper Bell mine in the autumn of 1901, and at that time the intention was to push development work as rapidly as possible.

Index.—The property of the Index Mining Company, of which Mr. Lot Wilbur, of Snohomish, Washington, is president and general manager, consists of five claims located about two miles southeast of Index, and south of the Skykomish river. The mine is reached by a trail built by the company from a point upon the Great Northern Railway about one and one-half miles east of Index. This trail is something over a half a mile in length, and crosses the south fork of the Skykomish river by a suspension bridge, also built by the company. The five claims owned by the company are located upon three distinct ledges,

only one of which has been developed thus far. This ledge strikes northeast and southwest, and dips about one in three to the northwest. It averages about three feet in width, and although all of the vein matter contains some metallic contents, considerable concentration of the ore is found along both walls, forming two distinct pay streaks. The hanging-wall of the ledge is remarkably distinct and regular, and parts readily from the vein matter. The ore consists of bornite and chalcocite (copper glance), the latter occurring in greater amounts as depth is reached.

The development work, up to August, 1901, consisted of three drifts, the lowest having been driven 535 feet, with a shaft 70 feet deep, located about 160 feet from the portal; the second drift, 180 feet (vertically) above the first was 180 feet long, and from this opening a 35-foot raise has been made, 80 feet from the portal; the upper drift, 200 feet above the second, was 243 feet in length. Four car loads of ore have been shipped from these workings, and at the above date a considerable amount of very high grade ore, in sacks, was stored at the mine. No work was done during the summer of 1901. The only surface buildings consist of a small bunk-house, blacksmith shop and sorting shed.

Index-Bornite.—The Index-Bornite Copper Mining Company owns two claims, the Barry and the Hillside, located two and one-half miles east of Index. These claims are both upon one two-foot ledge, carrying bornite. The development work begun in June, 1899, consists of a 50-foot tunnel and a shaft 70 feet deep, and is stated to have cost together with some surface work, about $1,500. Surveys have recently been made for a second tunnel, to tap the ledge at a depth of 200 feet. The ore, besides its copper contents, also carries some silver, three assays made by Mr. C. R. Redding, of Index, showing 6.2, 3.8 and 8.6 ounces respectively of silver per ton; copper assays upon the same samples showing 16.1, 11.1 and 58.9 per cent. respectively.

Index-Independent.—The Index-Independent Mining company owns three claims about five miles southeast of Index. The property lies about one mile south of the railroad, from which it is reached by trail. The three claims, the Independent, Copper King, and Defiance, are all located upon the same vein, which

strikes north six degrees east and stands nearly vertical. Up to the present time the only claim developed is the Independent, upon which about 900 feet of tunneling, drifting and cross-cutting has been done. The ore consists of chalcopyrite, bornite, and chalcocite (copper glance), bornite being in excess; the gangue is mostly quartz, although some calcite is found in places. The country rock is granite. One carload of ore, whose assay value was $98.98 per ton has been shipped. (Ben. Evans, Index.)

Gunn's Peak.—Three and one-half miles northeast of Index lies the Gunn's Peak property, consisting of four claims, owned by the Gunn's Peak Copper Mining company. These claims are located upon three ledges of chalcopyrite, which intersect at a point about 100 feet ahead of the tunnel now being driven. The main ledge, called the Rainbow, runs northeast and southwest, and shows a width varying from one to thirty feet on the outcrop, which has been uncovered at points for a distance of 1,500 feet. The total development to date consists of about 350 feet of tunneling, and 100 feet of cross-cuts. Average samples are stated to assay as follows: Copper, 11.4. per cent.; silver, $1.92; gold, trace. The mine was opened in July, 1899, and the cost of all development work done both underground and on the surface s estimated at $7,000.

Other properties in the Index district which are sufficiently promising to deserve special mention are the North Star, owned by the North Star Mining company; the Forty-seven, owned and managed by Mr. H. McKinnon, Index; the Kitanning Copper Mining Company, Mr. W. C. Rutter, Index, superintendent; the Climax, Copper King, Nonpareil, Trident, and Mammoth.

KING COUNTY.

The broad mineral belt in which are located the mines of Monte Cristo, Silverton, and Index extends southward into the eastern part of King county. Most of the active development work in this county has been done in the territory tributary to the line of the Great Northern railway, on the streams flowing

northward into the south fork of the Skykomish river. Salmon creek, Money creek, Miller river and Foss river are the principal tributaries on which active operations have been carried on, while to the southward across the divides from the headwaters of those streams, many claims have been located on territory which is drained by Tolt river and the various branches of the Snoqualmie. The general physical features are much the same throughout the district. Except along some of the larger river valleys the topography is extremely rugged. Bordering the streams sharp granite peaks rise to a height of from 6,000 to 8,000 feet above the sea, their higher and steeper slopes more or less destitute of timber on account of the frequent and destructive snow-slides of winter and early spring. The vein matter is usually of a softer nature than the surrounding country rock and for this reason many of the small lateral streams have chosen the veins for their channels. This has simplified the process of prospecting very greatly and therefore has been a factor in the development of the district. The prevailing country rock is granite, or closely allied rock, with a ramifying system of dykes of many varieties.

In the Miller river district it has been observed that the main joint plains have an approximate east and west direction and cross the main stream almost at right angles. In many of the prospects which have been opened up it is found that the ore has been deposited along these joint planes. The granite for some distance on each side of the vein frequently has some of its minerals replaced by ore so that it is often difficult to locate the exact contact between the vein and the wall rock. It often happens that parallel joints filled with ore are connected with each other by joints running at right angles to the main joints, thus making it very difficult to follow the main ore body. Many of the veins are, in part at least, replacement veins; that is, the ore, besides filling the previously existing fissures, has also more or less impregnated the wall rock on both sides of the vein. This is usually the case where the ore body is found to be more than a few feet wide.

Surface prospecting, in the higher parts of the district, is practically confined to the summer months on account of the deep snows of winter. The country is well watered; innumerable little rivulets fed by the snows and rain come trickling down

the mountain sides and unite to form torrential streams whose potential water power is one of the great resources of the district. This power can be harnessed at comparatively little expense, and it is a foregone conclusion that all the power employed for hoisting, lighting, and other purposes in the mines of this region will be furnished by the streams. Some of the mining companies have already made elaborate plans for utilizing the water power.

Below will be given brief descriptions of a few of the representative mining properties of that portion of King county that has just been described.

Great Republic.—The Great Republic Gold Mining Company has a group of ten claims on Miller river, about one and one-fourth miles from the town of Berlin, on the Great Northern Railway. The company has done about 1,100 feet of tunnel work on the claims and a considerable quantity of ore has been taken out. The principal values are in antimony, with small amounts of gold and silver. A five stamp concentrator has been installed at the town of Berlin for treating the ore.

Mono.—On the east side of Miller river, about two and one-half miles north of the town of Berlin, on the Great Northern Railway, is located the Mono group of eight claims belonging to the Co-operative Mining Syndicate, of Seattle. There is a good wagon road for about a mile, and a trail from this point to the claims. In the development of the property an upper tunnel has been driven for 80 feet, from it a drift 90 feet long has been made, and a winze 52 feet deep has been sunk. A second tunnel 140 feet lower down has been driven for a distance of 250 feet. Still lower down on the mountain side a tunnel has been driven 716 feet long, but the ore body has not been reached. Assays give an average value of about 4 per cent. copper, $1.25 in gold and $1.75 in silver per ton. The chief minerals are chalcopyrite and arsenopyrite.

Metropolitan.—The Metropolitan property is on the west side of Miller river, about nine miles from the Great Northern Railway at Berlin, and joins the Cleopatra property. Active development was only begun in August, 1901, and up to date this has cost about $2,000. The vein is about 16 feet wide at its maximum. The chief values are in gold and silver. (H. J. McIntosh, superintendent.)

Apex.—At the head of the west fork of Money creek, about eight miles southwest of Skykomish, and six miles from the nearest point on the Great Northern Railroad, is situated the Apex mine, upon which considerable work has been done. The vein averages about four feet in width and dips about 22 degrees to the southeast. The average assay value is about $35 in gold and $15 in silver and lead. The principal mineral is arsenopyrite.

This property was first opened in 1893, and up to the present time development work aggregating a cost of $15,000 has been done. Tunnels of a total length of 1,800 feet have been driven, with about 60 feet of stopes. The ore was carried out to the railway by means of pack animals. The smelter returns on the 300 tons of ore which have been shipped aggregate $15,000. Water power is used to operate the ventilating fan which is used in the longest tunnel. (John Maloney, Skykomish.)

Yellow Jacket.—The Yellow Jacket group of ten claims is located on the west side of the east fork of Salmon or Roaring creek, and on the south side of the pass leading into the Golden Tunnel basin. It is about three and one-half miles from Baring station on the Great Northern Railway. There is a good wagon road for about one-third of this distance and the rest of the way is by a trail. Development work was begun on the property in June, 1900, and up to the present time about $9,000 has been expended. The amount of underground workings, including tunnels and crosscuts, is approximately 540 feet. A tunnel has been run along the hanging wall, and crosscuts made every 100 feet. The vein upon which the work has been done has a strike that is nearly east and west and a dip southward at an angle of about 60 degrees. The average assay value or the ore is about $16, nearly all gold, but with a trace of silver. It is in part free milling, but there is some sulphide ore present.

Climax.—The Climax property is about four and one-half miles southwest of Baring, on the Great Northern Railway, and is located on the south end of Little Index mountain. There are eight claims in the group. About 200 feet of tunnel has been driven and a large number of surface cross-cuts made. The principal minerals are bornite and chalcopyrite, carrying silver and copper. The property was first opened in 1897, and since

that time about $4,900 has been expended in development work. No regular shipments have yet been made, but about ten tons of ore have been packed out in order to make a smelter test. This ore assayed from $50 to $100 per ton.

Carmack.—The Carmack Gold and Copper Mining Company has a group of five claims on the south fork of the Snoqualmie river, about 22 miles southeast of the town of North Bend, near the point where the wagon road over Snoqualmie pass crosses the south fork. This property was opened up in 1899 and up to the present time the company has expended about $15,000 in development work. About $3,500 of this has been used for hoisting machinery, buildings and other surface improvements. They have driven 375 feet of tunnel and shafts. Three veins have been worked, the first 12 feet in width, the second two and one-half and the third one foot. Up to date about 20 tons of ore have been shipped, having a total value of $1,200. The values are in gold, silver and lead.

Dutch Miller.—The Dutch Miller property is situated a very short distance west of the main divide of the Cascades. From it the drainage is westward to the middle fork of the Snoqualmie, and northward to Foss river, a tributary of the Skykomish. The outcrop upon which the location was made in 1896 stands at an elevation of a little less than 5,700 feet above sea, and at a distance of about eight miles from the Great Northern Railway at Foss river crossing. The ore vein has a maximum width of eighteen and one-half feet, and strike of north 70 degrees west. The principal mineral is chalcopyrite, and the principal values are in copper and gold. Several small shipments of ore have been made to a smelter, the returns averaging $37.65 per ton after the smelter charges were paid. The development work done consists of a shaft, a tunnel, and a considerable amount of open or quarry work upon the main ore body. The cost of all improvements made upon the property approximates $14,700. (H. P. Fogh, president, Seattle.)

KITTITAS COUNTY.

The southeastern half of Kittitas county lies within the domain of the Columbia lava, which does not contain as far as known any metalliferous deposits. On the other hand the northwestern half of the county, composed of the typical rock formations of the northern Cascades, has within it at several places important ledges of ore. These are found more especially to the southward and westward of Mt. Stuart. On Clealum creek and its several branches the ore veins are easy of access and many of them have reached a fair stage of development. In regard to the mining properties of this region sufficient data is at hand for a description of the iron ores only, which is given in another section of this report. Along Swauk creek, in about the central part of the county, the most important placer gold deposits of the state occur, as far as known, and a brief description of these will now be given.

SWAUK DISTRICT.

As early as 1867 placer gold was discovered on Swauk creek in the vicinity of Liberty, and the region has been a good producer ever since, but like all old placer camps, in its history it has suffered a series of fluctuations. The earlier methods of working the pay gravel were more or less wasteful and inefficient and as newer and more economical methods are being introduced it is found that ground can now be made to pay which formerly had to be passed over. The gold is found in the Pleistocene gravels which constitute the floor of the valley, and which occur also as terraces at varying altitudes above the present stream level. The country rock is sandstone and shale of early Tertiary age, cut by a large number of basaltic dikes. Along the contacts between the dike walls and the sandstone are many brecciated veins from two to six feet wide carrying free gold in a gangue of quartz and calcite. These veins have been worked to a considerable extent and are usually considered as the origin of the placer gold now found along the streams. Good pay gravel has been found on Swauk creek between the mouth of Baker creek and the mouth of First creek. Below First creek fine gold in

small quantities has been found all the way down to the mouth of the Swauk, and recent discoveries of pay gravel in the vicinity of Thorp would seem to inspire the hope that good pay may be found farther down the Swauk than has yet been thought possible. A considerable amount of gold has been taken out of Williams creek, which enters the Swauk at Liberty. All the good pay gravel is found within three or four feet of bed rock and about seventy or eighty feet below the present level of the stream.

The largest nugget yet found in the district was found within the last year on the Elliott claim, on Williams creek, and had a value of $1,100. Another nugget, $1,004 in value, was found on a bench of Swauk creek above the mouth of Baker. Fine gold may be had by panning almost anywhere from the surface downwards, but not in sufficient quantities to pay with the present methods of working. Owing to an insufficient supply of water in the streams sluicing and hydraulicking can only be carried on during the short seasons of high water in fall and spring. Along Swauk creek good pay gravel has been found on bed rock along the terraces bordering the stream, which are sometimes above the level of the present stream bed. On Williams creek and its tributaries shafts must be sunk seventy or eighty feet to bed rock on the old channels and the gravel hoisted to the surface to be washed. Considerable water has been encountered in these workings, sometimes to such an extent as to cause an entire suspension of operations.

The gold found in the stream gravels is all more or less waterworn. Along the talus slopes bordering some of the creeks and gulches fine wire and crystal gold has been found in paying quantities. The gold of Williams creek and its tributaries is supposed to have come from the western slopes of Table mountain, where these streams have their source. On Baker creek and on Swauk, above the mouth of Williams, the gold is probably derived from the Teanaway range on the west. The Williams creek gold is worth more per ounce than is that of Swauk above the mouth of Williams, owing to its smaller percentage of silver. The Baker creek and upper Swauk gold is worth about $13.50 per ounce, while that on Williams creek and its tributaries is worth $14.50 to $15 per ounce.

It is not possible to form even an estimate of the total output of these placers. The early workers did not keep any accurate

record of their output, and the present operators are keeping their information to themselves. At the present time there are several companies and individuals at work on Williams creek and its tributaries and on Swauk creek. Hydraulic operations have been carried on for several years with varying success. There is a very large amount of gravel that has never yet been prospected and which may be reasonably supposed to contain some good pay streaks, so that for a number of years to come we may look for a more or less steady output from this district.

PIERCE COUNTY.

The coal deposits of Pierce county have been known for many years, and the coal mines have now reached an advanced stage of development, contributing very greatly to the wealth and prosperity of the county. In the last few years a vigorous search has been made for metalliferous deposits, and the seeking has not been wholly in vain. A mineral belt has been discovered in the central part of the county, having a general north and south course, and lying between the coal-bearing sandstones on the west and the comparatively recent lava flows of Mount Rainier on the east. This belt is not large, but at different places within it some valuable ledges of metallic minerals have been found. The most important veins of ore as far as known occur on the Carbon river, in the neighborhood of Fairfax, and this district will now be described.

CARBON RIVER DISTRICT.

BY WM. S. THYNG.

The Carbon river district is located in the southeastern part of Pierce county, mostly to the westward and northwestward of Mount Rainier, many of the properties being even upon the lower slopes of that mountain. The district is reached from the town of Fairfax, the terminal of one of the Northern Pacific coal routes. This town, which is located to the west of the principal

properties, will be their natural shipping point when the mines begin to produce ore. Fairfax is forty-two miles from Tacoma by rail. At the present time probably the most important properties in the district are those of the Washington Co-operative Mining Syndicate and of the Montezuma Mining Company. These two companies, in addition to their copper mining interests, are at present developing upon a large scale some extensive coal deposits at Fairfax. The companies are operating in very close harmony and it is their intention to carry on their future mining operations in the district in conjunction.

Surprise.—Probably the most important group of claims in this district is what is known as the Surprise group, located on the east slope of Bald mountain, on Shiplake creek, ten miles by trail northeast of Fairfax. The country, as might be expected in that locality, is extremely rough, the steep slopes of the mountain side giving good facilities for mining operations, it being possible to attain considerable depth without sinking shafts and to avoid the necessity of building expensive pumping plants. Both water power and timber are practically without limit. The Surprise group comprises thirteen claims, twelve of which lie on a magnetic east and west line, while the thirteenth claim, known as the Hog Back, located near the center of the group, lies in a north and south direction. All of the development work to date has been done upon the Surprise claim, the most southeasterly one of the group. Upon this claim three distinct ledges are found. The development aggregates 365 feet of tunneling and drifting, but to the present time only 40 feet of depth has been reached by the main tunnel or drift. The company owning the property has recently acquired a right in a tunnel being driven by the Clipper mine at a vertical distance of 300 feet below, from which tunnel it is proposed to run a crosscut 360 feet to the main Surprise ledge. By the use of this tunnel a considerable depth of ore may thus be obtained and the work of mining considerably facilitated. The ledges on the Surprise claim carry both chalcopyrite and bornite and with these considerable hornblende is associated. The main ledge upon which all of the work has been done to date, averages between four and five feet in width, with a distinct pay streak of 22 inches; its dip is seventy degrees to the southward and very

uniform. The vein occupies a true fissure in a country rock of syenite, the gangue matter closely resembling this country rock.

Upon the Hog Back claim mentioned above as the only one of the group running north and south, three distinct ledges are found, with chief values in gold. The gold is associated, however, with some small amounts of copper and iron, chiefly chalcopyrite. The elevation of the main tunnel, at what is called the headquarters camp, is 4,160 feet above sea level.

During the summer of 1901 a considerable amount of development work was done upon this property, both underground and in surface improvements. It is the intention of the owners to begin very soon the operation of the property upon a large scale. A small air compressor has been installed at the mouth of the Clipper tunnel for use in driving the above-mentioned crosscut to the Surprise ledge, and it is understood that considerable work has already been done upon this crosscut.

Clipper.—This property is located southeast of and immediately adjoining the Surprise group. Comparatively little work has been done outside of the main tunnel that was mentioned above. Mr. T. H. Wilkins, address Fidelity building, Tacoma, is the chief owner of the property.

Chicago.—The Chicago group of six claims, owned by the Montezuma Mining Company, is located about nine miles from Fairfax at a short distance from the main trail leading to the Surprise mine. This group is then about two miles east of the Surprise. The property has not up to the present time been developed, nothing beyond assessment work having been done. The ore is chalcopyrite, carrying some small amounts of gold and occurs in a fissure vein in diorite.

East Lake.—The East Lake group of six claims, owned by the Washington Co-operative Mining Syndicate, is another property not as yet developed. This group is located about one-half of a mile due east of the Surprise, being between that property and the Chicago. A number of veins are found here, all with a general eastward strike. The ore is chalcopyrite, and the country rock is syenite.

Blue Star.—The Blue Star group, consisting of fourteen claims, is located on Cowcowan creek, a tributary of the Carbon

river, and is six and one-half miles by trail from Fairfax. There are nine known veins or ledges running through these claims, most of them strong and well defined and showing at the outcrops widths varying from eight inches to eight feet. Most of these ledges strike east and west; but one well-defined vein is found running almost due north and south. The ore is chalcopyrite of good appearance, with varying values in both gold and silver. The country rock is gneiss. Comparatively little development work has as yet been done upon this property. A tunnel having a length of about 40 feet has recently been driven, and it is understood that the present owners propose immediate development work.

Tacoma.—This property is located upon the Mowich river, seventeen miles, by pack trail, southeast of Fairfax. Four claims are embraced in the property, owned by the Washington Co-operative Mining Syndicate. Adjoining these claims the Montezuma Mining Company owns a group of five claims. The country is heavily timbered and is provided with an abundance of water power. The main ledge, upon which all development work to date has been done, averages 25 feet in width. It strikes northeast and southwest and dips eighty degrees to the southeast. The outcrop is exceedingly well defined upon the north side of the Mowich river, the mountain rising very abruptly from the creek bed, with practically no vegetation upon it. The ore is chalcopyrite, disseminated throughout the ledge, but as development has progressed a rich streak about three feet in thickness, consisting of chalcopyrite, intimately mixed with calcite, is found along the foot wall. The property was first opened by a drift, along the hanging wall, located about 175 feet above the bed of the creek. This drift has been driven for 200 feet along the vein, with five cross-cuts to the foot wall aggregating 100 feet in length. Late in the summer of 1901 the company installed a small air compressor and is now engaged in driving another drift about 125 feet below the first, working with machine drills. The air compressor is run by water power. The ore is stated to contain from five to thirty-three per cent. in copper, with $2 in gold and $3.50 in silver per ton, or in all having an average value of $60 per ton. This property is admirably located for mining work and may be expected to give a good account of itself in the near

future. No ore except for purposes of experimental treatment has as yet been shipped.

It is the purpose of the Washington Co-operative Mining Syndicate to erect a smelter adjoining its coal property at Fairfax. The company will then be practically self-contained and in a position to smelt its own ore as well as those of the other properties of the district. If the calcite, occuring with the ores along Mowich river, is found to continue in depth, it will be of great importance in forming a flux in smelting.

LEWIS AND SKAMANIA COUNTIES.

ST. HELENS DISTRICT.

St. Helens mining district is located in part in Lewis county, but the main portion of it lies in the northwest corner of Skamania county, north of Mount St. Helens. Spirit lake, which marks the southern boundary of the district, is a body of water five miles long by one or two miles wide, lying about six miles north of the summit of Mount St. Helens. The district is reached either by stage road from Castle Rock to Spirit lake by way of the middle fork of the Toutle river, sometimes known as Green river, or by wagon road and trail from Chehalis by way of the Cowlitz and Cispus rivers. There is another trail up the north fork of Toutle river, which connects with the wagon road at Olson. The district is situated far back in the mountains, but by following the larger valleys no very heavy grades are encountered. The topography of the district is very rugged, resembling in some respects a deeply dissected plateau. Spirit lake lies at an elevation of 3,100 feet above sea level. Mount St. Helens lies immediately to the southward, while to the northward are a number of peaks, the highest one of which is 6,300 feet.

The country to the north and east of Spirit lake is of syenite. A large number of porphyry dikes cut through the syenite, having a general strike of north 25 to 30 degrees west, and dipping westward 60 or 70 degrees. To the northwestward of the

syenite belt the country rock is mostly quartzite, more or less broken up, traversed by a series of veins standing almost perpendicular and whose general strike is northeast and southwest. The veins of the district are often of great width and carry sulphide ores, mostly of copper and iron, with some lead. They are true fissure veins and are found along the contact between the porphyry dikes and the country rock. They can often be traced for considerable distances.

The valleys are heavily timbered with fir, cedar, yellow pine, hemlock and larch. Higher up on the mountain sides the timber gets smaller and more scarce as the timber line is approached. Some of the finest timber in the state is found along the north fork of Toutle river. The small mountain streams furnish an abundance of water-power, which some of the mining companies are planning to utilize as soon as the machinery can be gotten in place.

Discoveries of metalliferous deposits in the district were first made in 1891, and the district was organized on September 22, 1892. It was first known as the Green river district, but owing to confusion arising between it and the Green river coal district of King county, the name was afterwards regularly changed to the St. Helens district.

At the present time the greatest activity in the Spirit lake region is in the mines on Paradise creek, formerly known as Lake Canyon creek. There are several groups of claims belonging to the Mining Corporation, Limited, of Portland, represented by Dr. Henry W. Coe. They are pushing development work on the Sweden, Bronze Monarch, Norway, Young America and other groups. Winter supplies were taken in during the summer of 1901 in order that work might be actively prosecuted during the following winter.

Sweden.—The Sweden group embraces eight claims, located at the mouth of Paradise valley on the north shore of Spirit lake and six miles northwest of Mount St. Helens. Besides smaller veins there is the Paradise lode thirty-three feet in width, which has been traced a distance of three thousand feet. The veins strike north fifteen to thirty degrees west, and dip southwest about seventy-five degrees. A tunnel is being driven along the foot wall of the Paradise lode, and at latest reports had reached a depth of fifty feet. The ore which is being taken out of the

tunnel averages in gold \$3.25, silver six ounces, copper nine per cent. There is now on the dump four hundred tons of ore, carrying total values estimated at nine thousand dollars. The company is now installing machinery for a large water power plant which when completed will furnish power for drilling, hauling, lighting, etc.

Bronze Monarch.—Adjoining the Sweden group on the northwest, and upon the same great lead, is the Bronze Monarch group upon which a tunnel is being driven, now three hundred feet in length. There are now about one thousand tons of sulphide ores on the dump ready for treatment which the owners of the property think will average twenty-eight dollars per ton in gold, silver and copper.

Norway.—One thousand feet farther up the mountain from the Bronze Monarch another tunnel is being driven on the same vein on the Norway group, consisting of nine claims. The tunnel is now in a distance of three hundred and fifty feet. The ore is of the same character as that found in the two lower tunnels. The vein here is about twenty-five feet in width. There is about one thousand tons of ore on the dump valued at \$28,000.

Young America.—The Young America group consists of five claims adjoining the Norway and Bronze Monarch groups on the northeast. The vein which is now being worked shows in the bed of the creek a width of twelve feet, and can be traced by its outcrop for more than two thousand feet. A tunnel fifty feet long has been driven on the vein.

The Mining Corporation, Limited, owns other claims along the lake front and in the immediate vicinity and this winter (1901-2) are building boats and barges on the lake for transportation of the heavy machinery and ores during the summer of 1902.

Chicago and Yellow Metals.—About two and a half miles northeast of the lake are the Chicago and the Yellow Metals groups, also belonging to Dr. Coe and his associates. The property is reached from Spirit lake by way of the trail over Norway pass, having an elevation of seven hundred and fifty feet above the lake. There are about twenty claims in the two groups, which are located in a general way upon the extension of the

great Norway-Sweden-Denmark vein. This vein has been identified upon the two Octavius claims at the southern end of the group near the bottom of the valley of North Toutle river. A tunnel two hundred feet long has been driven on the Chicago claim and a cross-cut started which will reach the vein at a depth of six hundred feet. The vein at this point is twenty-five feet wide and carries gold, copper and silver which have a maximum value of $60 per ton.

Samson.—The Samson group, sometimes known as the Earl group, consisting of twenty claims, lies four miles northeast of the Chicago and Yellow Metals group, at the base of Goat mountain on North Toutle river. About six hundred feet of tunnel has been driven on the property but only with indifferent success. It has now been taken under a working arrangement by the Mining Corporation, Limited, and this company is driving a prospect tunnel to crosscut small veins which outcrop along Samson creek. At the base of the mountain below the tunnel there is a big ledge or deposit five hundred to a thousand feet wide, all mineralized, but of very low grade, averaging not more than three dollars in gold, silver and copper.

Index.—Two and a half miles to the northwest of the Chicago lies the Index group, which has been owned for many years by the Olson Brothers, but who have recently given a two years' working bond upon the property to the Mining Corporation, Limited. This company is now contracting for half a mile of tunnel work upon this and their other properties for the spring of 1902.

Polar Star.—The Polar Star mine, owned by the Cascadia Mining and Development Company, is located two and a half miles below the Samson group on the north fork of Toutle river near Black Falls. A crosscut tunnel has been driven a distance of eighty feet, revealing a mineralized ledge twelve feet wide carrying copper and iron sulphides, with from six inches to three feet of solid ore. Seventy-five feet from the mouth of the tunnel a drift has been run eighty-four feet and considerable ore taken out. A shaft has also been sunk to a depth of thirty-five feet.

Juanita.—The Juanita property, owned by Messrs. U. M. Lauman, W. A. Reynolds, and David Stewart, is located about

half a mile from the source of the north fork of Toutle river. During the summer of 1901 a tunnel 50 feet long was driven. The vein is six and a half feet wide, and carries values averaging $37 in gold and copper. The strike of the ledge is about north 10 degrees west. About $500 has been spent in development work.

Washington.—This property is situated near Norway pass. It has upon it a well defined fissure vein which makes a good surface showing. The vein strikes nearly north and south and dips about seventy-eight degrees to the westward. A tunnel 50 feet long has been driven upon the ledge.

Ripper and Chief.—The Ripper and Chief properties, belonging to Messrs. McClure and Hostetter of Agate, Washington, are located about four miles northeast of Spirit lake. Both claims are on the same lead, which is about four feet wide, and which carries gold and copper yielding maximum values of about sixty dollars per ton. The chief minerals are galena and chalcopyrite. About one thousand dollars has been spent in development work.

REDUCTION PLANTS IN WASHINGTON.

BY MILNOR ROBERTS.

Washington produces a great variety of ores, requiring many kinds of treatment to extract the values, thus necessitating reduction plants of various types. Examples of nearly every stage of development in the industry may be seen in the state, from the pan, cradle, and sluice of the wandering prospector, to the great custom smelters, handling hundreds of tons of ore daily, with a minimum loss of the metals.

The headings under which the reduction plants will be described are as follows:

I. Smelting works.
II. Chlorination and cyanidation plants.
III. Stamp mills (amalgamation.)
IV. Arrastras.
V. Concentrators and combination plants.

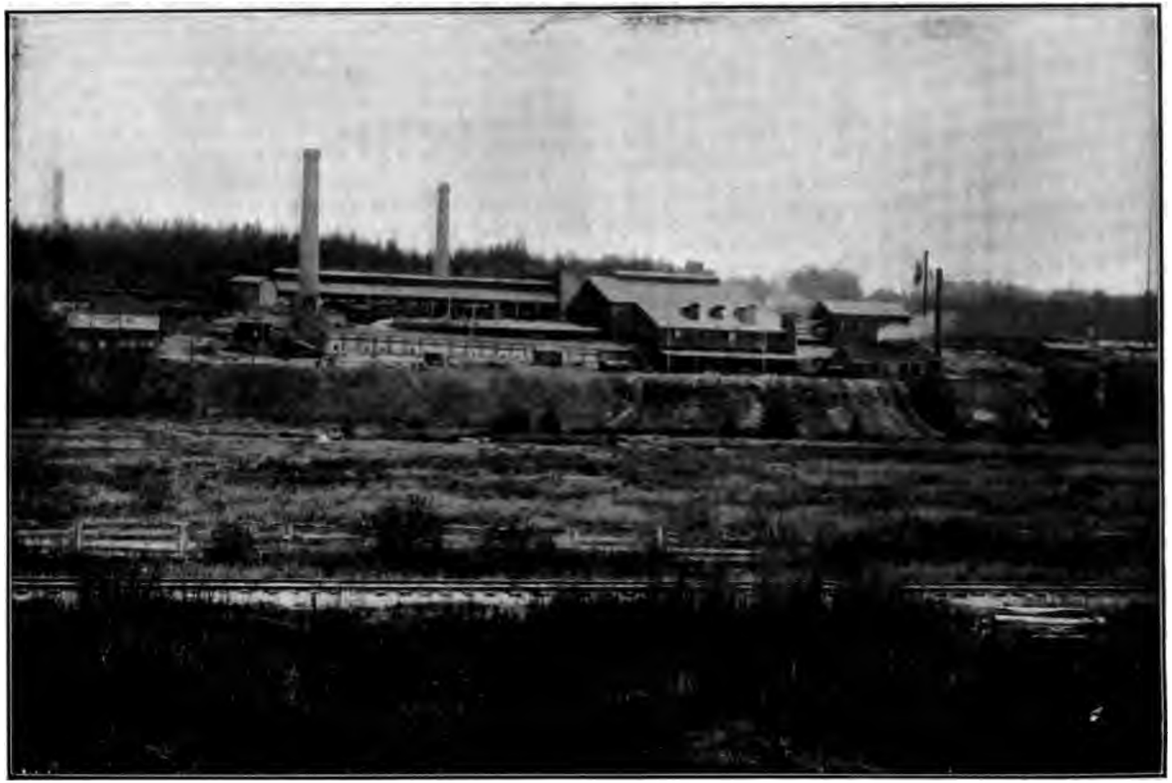
Although no attempt is made to enumerate all of the reduction plants in the state, except the smelters, the following pages contain brief descriptions of some of the most important representatives of the classes mentioned above.

I. SMELTING WORKS.

THE EVERETT SMELTER.

[The Puget Sound Reduction Company.]

Everett, "The City of Smokestacks," owes her title in no small measure to the smelting works of the Puget Sound Reduction Company, which are situated on the outskirts of the city. Although at present no company operating in the Pacific Northwest is fitted to undertake the work of treating crude ores to produce refined gold, silver, and copper, yet the Everett smelter turns out these three metals in a condition that requires only a



THE EVERETT SMELTER, OWNED BY THE PUGET SOUND REDUCTION COMPANY.

short final process — that of parting the dore bars and electrolytic refining of the blister copper — to put all in shape for the market. In addition to this, the company has recently built and is operating the only arsenic plant in the United States.

ORES.— The supply of ore is drawn from very wide sources — from Alaska, South America, and occasional shipments from the Orient, as well as from the states of Montana, Idaho, Oregon, California, Nevada, and British Columbia. This company holds contracts for the output of some of the most important producing mines in the State of Washington; the Cedar Canyon group, the Forty-five, and the Monte Cristo. Other regular shippers are the Rambler, the Hercules, the Bunker Hill and Sullivan, and the North Star. The latter furnishes thirty car loads of ore a month, carrying about 50 per cent. lead. Occasionally a shipment of quite rich ore or concentrates is received, a recent example being several hundred tons of four-hundred-dollar ore from the Tonapah Mining Company, in Nevada.

SAMPLING.—On arrival, the ore is distributed, the oxidized ores being sampled at the sampling works, while the roasting ores are crushed, sampled and handled at the sulphide mill.

Owing to the wide difference in the character of ores treated, the system of hand sampling is still pursued. Sampling of car load lots is usually done by taking a tenth or a fifth of the whole. This sample is run through a Blake crusher and a set of rolls, and is then quartered repeatedly until reduced to 100 pounds. Such a weight can be conveniently crushed to pea size in rolls, and further reduced by quartering to three or four pounds, when it is dried, ground to 80 mesh by a small gyratory crusher, and sent to the assay department. When a small lot of ore arrives, after it is crushed, every tenth shovelful goes to the rolls for sampling.

ROASTING.—All ores which contain sulphur in excess of six per cent. are roasted. Mechanical furnaces are used exclusively, two with double deck, one single deck, and all mechanically fed. To meet the requirements of an increasing business, five Bruckner roasting cylinders of the largest size are being installed at present.

BLAST FURNACES.—Two blast furnaces are of large size, having an area of 36″ x 180″ between tuyeres. No. 1 has 20 tuyeres,

with a cold blast under 20 to 30 ounces pressure per square inch. Furnace No. 3 has an area of 42"x120". This is now used solely for the purpose of making 50 per cent. copper matte, but is about to be replaced by a furnace of the same size as the regular ore furnaces.

PRODUCTS.—The base bullion from the blast furnaces in the form of bars weighing approximately 100 pounds each, is assayed for gold and silver and sent to the refining department. About 500 bars are charged at one time into a reverberatory: the impurities,—copper, arsenic, antimony, etc.—rise to the surface of the molten lead, and are skimmed off from time to time with perforated ladles. These skimmings are returned to the blast furnace. The remainder is run into a circular zincing kettle 7 feet in diameter and 3½ feet deep, capable of holding 20 tons. A fireplace underneath, with blast connections, serves to keep the temperature of the lead bath just above the melting point of zinc. A weight of zinc equal to three times the amount of silver and gold present in the lead, is now added in the form of broad flat bars, easily melted. Instead of the customary three zincings, here the zinc is added in only two lots, and is mechanically stirred each time by a steam-driven propeller screw with four blades, revolving about 200 times per minute. The kettle is allowed to cool down to a temperature just above the melting point of lead, the gold and silver contents alloy with the zinc, which being lighter, gradually rises to the surface of the lead bath and is skimmed off. The process is finished when cupellation of small samples of the lead shows that the proportion of silver remaining is less than .24 of an ounce per ton.

The skimmings of zinc containing the gold, silver and a little lead, are charged into graphite retorts, along with powdered coke as a reducing agent. Crude oil is being burned under these retorts at the present time. The zinc is oxidized, passes over into a condenser and is there reduced to metallic zinc; this is tapped out from time to time, run into moulds, and sent back to the zincing kettle. Five or six hours time is required for retorting, and the loss of zinc in the whole process is less than 25 per cent. The resulting rich alloy of gold, silver and lead goes to a small concentrating reverberatory, one bar at a

time. As it melts, air is admitted to oxidize the lead to litharge, while the precious metals settle in the bowl of the furnace. The alloy is dipped out and run into bars of 85 pounds weight, containing a very small amount of lead. A tilting furnace is used for the last melting, during which the impurities rise to the surface and are drawn off. The balance is shipped in the form of dore bars to the Seattle Smelting and Refining Company. The dore bars are .990 to .995 fine in gold and silver; by the process of parting, they are separated into fine gold, for deposit at the United States assay office at Seattle, and fine silver, which is shipped by this company to the Orient direct.

The lead from which the values have been extracted by means of zinc, is run into a lower kettle (similar to the first), where it is again heated; after steam has been passed through it, slow cooling follows. A scum forms on the surface, which is removed, and the soft lead is run into 200-pound pigs, commercially pure. That portion made from imported lead ores is re-exported to the Orient, especially to the markets of Japan and China.

Copper matte, from the blast furnaces, is handled by the English reverberatory process, and the product, blister copper, is shipped to electrolytical refineries for segregation. After the elimination of the gold and silver contents, along with other impurities, the refined article is known as electrolytic copper.

The production of commercial arsenic was begun in the year 1901 and is now a regular branch of the company's operations. Several hundred tons have been produced at the rate of about five tons per day. Volatilized arsenic, together with antimony, sulphur, etc., from the roasting of Monte Cristo ore, is condensed in a series of chambers, then charged with one-fourth its weight of very pure coke into a refining reverberatory. The refined material, which is commercially pure, is sold and known as "Standard" arsenic, the only brand produced in the United States. Besides its use in the drug trade, a small amount of arsenic finds its way into many common products, notably paris green, glass, dyes, tanning mixtures, wall paper, paints and metallic alloys. In the year 1900 the United States imported 5,765,559 pounds of this article, mostly from England and Germany, but since then the demand has fallen off considerably.

THE TACOMA SMELTER.

[The Tacoma Smelting Company.]

The plant of the Tacoma Smelting Company is situated on the water front of Tacoma, about three miles west of the main shipping wharves. A length of nearly half a mile of shore land has been purchased by the company, and in the immediate neighborhood of the smelter an area of seven or eight acres of solid ground has been built up in the bay with slag. By means of this newly made land extending out into deep water, ocean vessels may now land at the company's short piers and discharge cargoes of ore within a hundred yards of the furnace doors. A railway track extends from the city along the bay shore through the smelter yards, with switches and bunker-tracks arranged to deliver ore directly into bins or roasters, as may be required. Passenger traffic with Tacoma is carried by the Point Defiance electric line, which runs near the settlement made up of the three hundred employes and their families.

No smelter on our western tide-water need lack material; Mexico, Central America, Peru, Chile, British Columbia, Alaska, and even Japan, all contribute their wealth of mineral, while the nearer districts, Eastern Oregon, various parts of Washington, the Cœur d'Alenes and Montana, assist the smelters by supplying variety in the ores, the prime factor in furnace operations. The Bunker Hill and Sullivan mine, in the Cœur d'Alene district, is daily supplying to this smelter an average of 75 tons of lead-silver concentrates, and the famous Alaska-Treadwell mine, on Douglas island, furnishes the same amount of gold concentrates. From all other sources combined, about 250 tons are received daily, placing the total day's work of the present plant at 400 tons. By the 1st of May, 1902, a large new copper blast furnace will be ready for operation, increasing the smelting capacity by one-half.

Sulphurets are roasted in three double-deck mechanical roasting furnaces, 12 feet wide by 140 feet long, capacity 70 tons in 24 hours. The pattern of these roasters is a very effective local modification of the Brown patent continuous slot and rail system. Instead of the usual fragile tile hanging from the roof-arch, an iron hood (cast in one-piece sections 4 feet long), containing the rail-block and leaving a continuous slot, prevents the heat of the roasting sulphides from injuring the chain and

wheels which convey the rabble-arms. One man on a shift is the whole force required to feed the ore into the upper deck of the roasters at the west end, below the ore-bins and freight cars. When the rabbles have carried the ore to the east end, it drops down to the lower deck and is carried back to the west end, having lost all but 3 per cent. of its sulphur during the 10 or 12 hours required in passage. The Treadwell concentrates need very little fuel to assist in the roasting, so that only the three upper fireplaces along the side are used to start the furnace, the four lower ones remaining cold.

The roasted ores, or concentrates, fall into a horizontal trough, through which runs an endless chain with conveying paddles attached. From this trough the material drops into a similar one at right angles, in which it is carried up a steep slope into a bin, and is then mixed by mechanical churning with two per cent. by weight of Roche Harbor lime. The moist, warm mixture is fed to a White Mineral Press (made by Chisholm, Boyd & White, Chicago), from which it emerges on a conveyor belt, in the form of circular briquettes, four inches in diameter and two inches high. The briquettes fall from the belt into cars with network sides; these cars are run into a flue filled with hot gases from the roasters. Four hours in such an atmosphere bakes the briquettes into cakes sufficiently hard to withstand being charged into blast furnaces without pulverizing.

By the first hand-labor employed since the ore has left the receiving bins, it is now weighed, wheeled to the charging floor, and mixed with other suitable ores, coke, lime-rock, matte and slag. There are four water-jacketed blast furnaces as follows: One small copper furnace 33" x 84", which handles nearly 100 tons a day, one lead furnace of the same size, and two other lead furnaces, 36" x 120", and 36" x 160", these latter treating 130 to 140 tons per day. A cold blast is used under 1.5 to 2 pounds pressure; the tuyeres have an automatic shut-off, to prevent the back-flow of furnace gases when the blast fails — a successful scheme patented by George Klink, one of the local furnacemen. The draft from each furnace is carried down to underground flues connecting with two large stacks, 115 feet high. A copper furnace built on the latest plans by the Allis-Chalmers Company, Chicago, is being erected at the western end of the plant, on the water's edge. Its capacity will be 200 tons, its size 42" x 160",

with steel jacket extending up to the charging door, and blast heated by stove to 800°. This furnace has its own stack, 150 feet in height.

The products at present are:

1. Lead bullion, which is shipped to the Selby Smelting and Lead Works, San Francisco.

2. Copper matte, containing about 60 per cent. copper; this is now being sent to the American Metal Company, New York, but with the new copper furnace, converters will be set up to make blister copper.

3. Matte from the lead furnaces, composition very variable, averaging about 2 to 4 per cent. copper, 10 to 15 per cent. lead and several ounces silver. This is crushed by rolls, roasted in two reverberatories (size 18 x 72 feet), and again fed to the blast.

4. Slag, of which the shells from the slag pots are re-smelted, and the remainder is used only to build ground on the water-front.

In the crushing and sampling department, numerous ore bins and sampling floors are provided. Two sets of crushing rolls, two Blake crushers, jaw-opening 7 by 9 inches and 7 by 11 inches, besides various appliances for hand sampling, crush the crude ore and matte, and reduce to a minimum the labor of preparing samples for assay. Mr. Peter Daly has charge of the assay department, where wet and fire assaying, and electrolytic analyses are conducted.

The Snoqualmie Falls Power Company supplies a current of 22,000 volts, which is transformed at the smelter to 440 volts, and is developed to an aggregate of 460 h. p. by four motors. A fifth motor of 75 h. p. will come into use hereafter to run the blast blower for the new copper furnace. The company's large steam plant has been kept intact as a precautionary measure. At present, however, steam is kept up in only one boiler, for use when the electric current fails. So many repairs are constantly needed about a smelter that it is almost a necessity to have a foundry at hand, as is shown by the amount of work done by the small cupola set up here. Over 350 patterns have been turned out by the local pattern-maker. The machine shop is fitted with a lathe, drill-press, planer, bolt-cutter, shaper, etc.

Under the careful and progressive superintendence of Mr. F. W. Clark, experiments are constantly being tried in quick

methods of handling the ores and slag, and in improving the furnace practice. Apparently, it is the aim of the management to maintain an establishment that shall be independent, so far as possible, of outside labor and sources of supply. Whenever practicable, the company prepares material of all sorts on its own ground, thereby avoiding delay in transportation and the losses due to market dealings.

THE NORTHPORT SMELTER.

[Northport Smelting and Refining Company, Limited.]

BY WILLIAM S. THYNG.

The Northport smelter, employing between 400 and 450 men, is operated in close conjunction with the mines of the British-America Corporation, at Rossland, British Columbia. In fact the Northport plant is now run exclusively upon the ore from the Le Roi and the Le Roi No. 2 mines, in Rossland. This ore is brought from mines to smelter, 17 miles, over the Red Mountain branch of the Spokane Falls & Northern Railway.

The smelter is located upon the east bank of the Columbia river, just above the town of Northport, in the northern part of Stevens county. The plant, under the management of Mr. Oscar Szontagh, has recently undergone a number of radical changes. It has been found that the ore may be smelted and a matte of the required grade for shipment produced without roasting, or calcining, the matte resulting from the first fusion, a practice pursued by the former management, and one which had been in vogue, in fact, since the smelter was built. When Mr. Szontagh was appointed general manager, in November, 1901, a new double-decked, straight line calcining furnace had just been completed, to be used in addition to the two single-decked calciners formerly employed. This new furnace, however, has not been used, and it seems probable that it will not be necessary, at least as long as Rossland ores alone are treated at the plant. These three calcining furnaces therefore lie idle at the present time.

Another important change over former practise was made during the spring and summer of 1901, when the double battery of stalls, in which a considerable portion of the ore was roasted, was torn out, with the intention of extending the roast yard and using longer heaps, in which form all the ore is now roasted.

The area which was covered by the stalls has not yet been utilized, however, it having been found that the original roast yard gives ample capacity for the present output of the plant.

All Le Roi ore is broken and sampled before leaving the mine at Rossland, and comes down ready for roasting. The ore from the Le Roi No. 2, however, is sampled at the smelter. As was before stated, all roasting is now done in heaps, the heaps measuring 350 feet long, 82 feet wide at the bottom, and 18 feet high. The raw ore, when piled, averages from 8 to 9 per cent. in sulphur, which percentage is brought down to between 3 and 4 in the roasting. In the operation, each ton of ore is tied up for from 30 to 40 days; this makes allowance for time used in piling and tearing down, the latter being generally begun before roasting is completed in the center of the heap. A total of about .02 cord of wood per ton of ore is used.

The company at present operates five blast furnaces, with a total daily capacity for 1,100 tons of ore; three of these furnaces measure 38 inches by 120 inches, and the other two, 42 inches by 160 inches, at the tuyeres. A sixth furnace, to have a daily capacity of 280 tons, is now on the ground, and is to be erected shortly; this last, unlike those already in operation, will be a boshed furnace.

It is aimed to produce a matte of the required grade for shipment, in two fusions, but three are sometimes found necessary. The ore treated averages about 2 per cent. in copper and 24 per cent. in iron. Matte from the first fusion contains generally from 25 to 30 per cent. copper and from 8 to 10 ounces of gold; the sulphur contents running about 25 per cent. All matte is shipped east for refining, the requirements in this shipping matte being: Copper, 40 per cent., or over; gold, 15 oz., or over; this grade matte also runs about 25 per cent. in sulphur. The amount of silver in the Le Roi ores, and consequently the amount in the final matte produced, varies rather widely, but probably from 26 to 30 oz. will represent a fair average in the matte.

All matte from the first fusion is cooled in spilling plates, to facilitate rapid cooling and its subsequent breaking up for charging into the furnace for second fusion; these spilling plates, which have been introduced here by Mr. Szontagh, are of cast iron, and measure 24 inches by 48 inches, by 2 inches in depth,

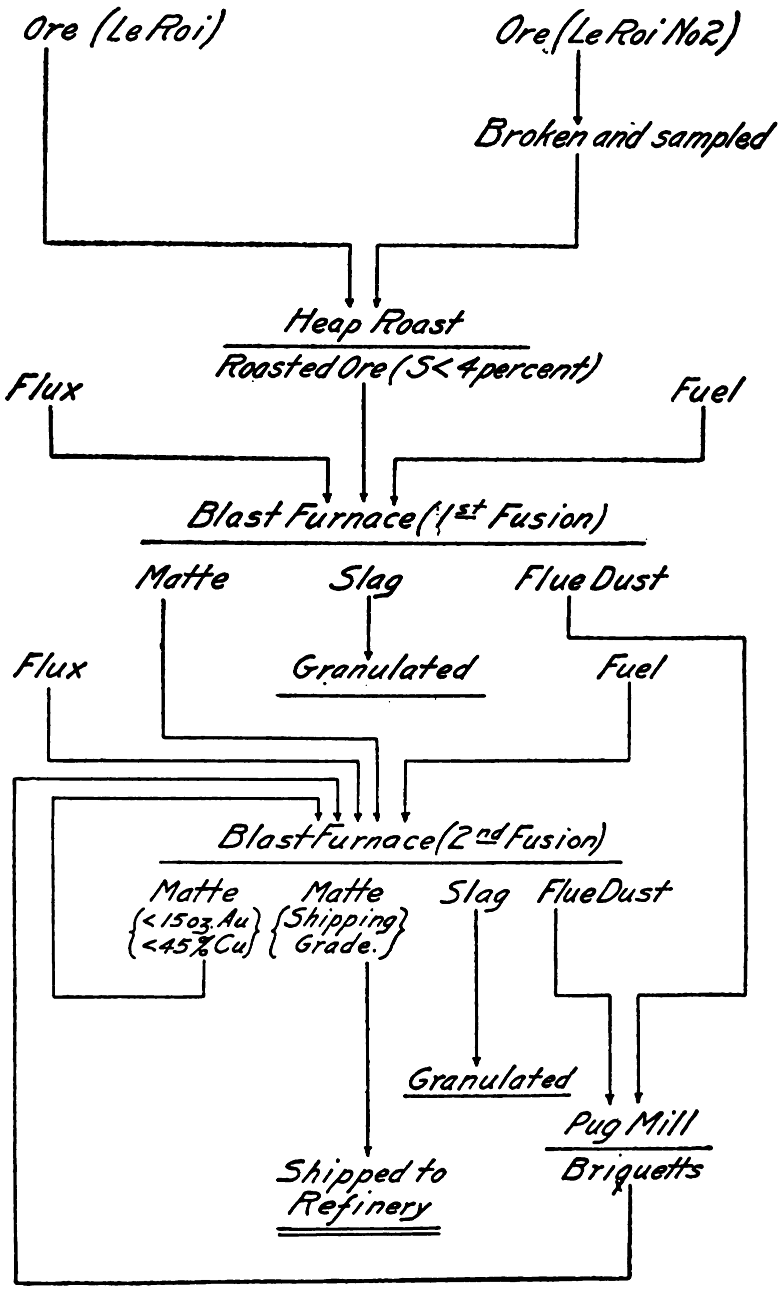
each plate thus having the same capacity as an ordinary matte pot.

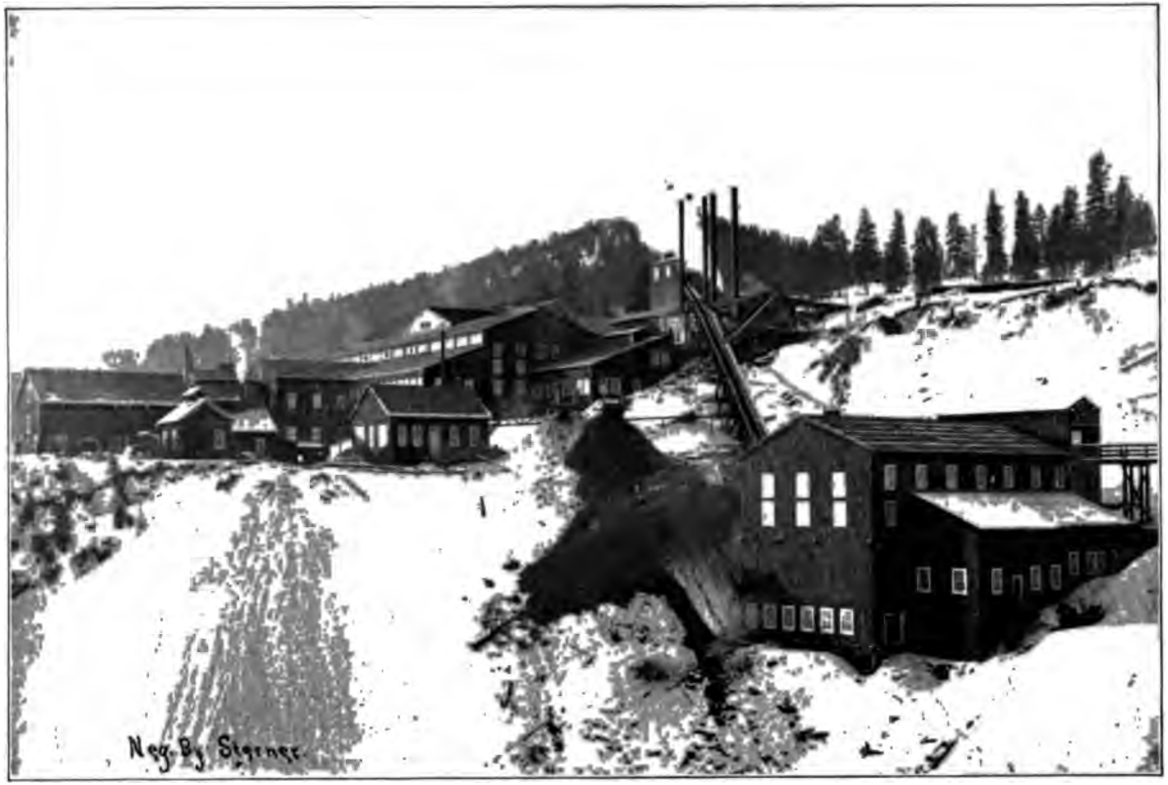
The dust chamber, which is 428 feet long, with a cross-section area of 110 square feet, is designed for easy and rapid discharge through side gates. With the plant running at its full daily capacity of 1,100 tons, about 15 tons of flue dust are caught and removed each day. This flue dust is briquetted immediately, using lime as a binding material, and is again put through the blast furnace. The stack at the end of the dust chamber is 182 feet high and 10 feet in square section.

All limestone used for flux is obtained from a quarry owned by the company, and located about four miles south of Northport, on the line of the Spokane Falls & Northern Railway. This limestone is unusually pure and free from silica. The coke used in the blast furnaces is obtained partly from the western part of Washington, and partly from the eastern states.

No figures have been given by the management as to the amount of matte shipped daily, or monthly, but assuming the average copper contents of the ore treated, as 1.8 per cent., and knowing the total daily capacity of the furnaces for ore to be 1,100 tons, we have: $1100 \times .018 = 19.80$ tons copper treated per day; 19.80 tons of copper contained in a 45 per cent. matte, which may be taken as about the average grade, are equivalent to about 44 tons of matte, which is perhaps not far from the daily output. These figures are, of course, very general, and may be taken only as representing an estimate.

A resume of the different processes employed in the transition from ore to shipping matte, follows in graphical form:


Ore (Le Roi)
Ore (Le Roi No2)
Broken and sampled
Heap Roast
Roasted Ore (S< 4 percent)
Flux
Fuel
Blast Furnace (1st Fusion)
Matte
Slag
Flue Dust
Granulated
Flux
Fuel
Blast Furnace (2nd Fusion)
Matte {< 15 oz. Au <45% Cu}
Matte {Shipping Grade.}
Slag
Flue Dust
Granulated
Pug Mill
Briquetts
Shipped to Refinery



THE REPUBLIC MILL, OWNED BY THE REPUBLIC REDUCTION COMPANY.

II. CHLORINATION AND CYANIDATION PLANTS.

THE REPUBLIC MILL.

[The Republic Reduction Company.]

At the mouth of tunnel No. 4 of the Republic mine, is situated the sampling mill of the Republic Reduction Company, which handles custom ores for the district in general, as well as the ore from the Republic mine. The reduction plant is located higher up the hill-slope, on account of lack of suitable space below. It is therefore necessary to hoist all the ore after crushing and sampling, and this is done by means of a self-dumping skip running on an inclined surface tramway 400 feet long, operated by a small friction hoist located at the foot of the tramway in the sampling mill. One of the main advantages in having the crushing and sampling performed in a building built for that purpose only, is the avoidance of placing heavy machinery in the roasting and cyanide plant, and the absence of dust there.

Receiving bins with a capacity of 500 tons occupy the top level of the sampling mill. From these bins the ore goes direct to a No. 5 Gates crusher and is carried by elevator No. 1 to a revolving trommel. The screened material goes to a set of rolls, 15 by 36 inches, high grade Gates, and the ore that fails to pass through the trommel is returned to another Gates crusher, style H, from which it falls again into elevator No. 1. Ore that has passed the rolls is ready for the Brunton automatic sampler. The main portion goes to one of the storage bins for sampled ore on the lowest level of the mill, while the sample portion goes by way of an elevator to small crushing rolls, and from thence to two more sampling machines, the final resulting sample being about one per cent. of the original weight. This small sample is treated by hand in the sampling room and reduced by quartering and small crushing machinery to a size and fineness suitable for assaying.

A tramway running under the lower storage bins serves to carry the sampled ore to the inclined skipway mentioned above. The skips dump their load automatically into the 500-ton storage bins on the top floor of the reduction mill. The latter is built

on seven different levels, vertical range 65 feet, and horizontal area 280 by 315 feet. Two revolving dryers, 5 by 26 feet, occupy the second level, while the main engine room and boiler house is situated on the north side of this section. Six return tubular boilers, 60 inches by 16 feet, with a combined capacity of 500 h. p., furnish steam for a 180 h. p. Lane and Bodley Corliss engine for driving the fine crushing machinery and dryers, an air compressor and a 40 h. p. engine and generator for electric lighting. An engine of 80 h. p. in the sampling department and three others elsewhere about the works complete the power plant.

On the fourth level stand the fine crushers, two sets of 15 by 36-inch rolls, two sets of 15 by 26-inch rolls, three 8-foot ball mills, and the usual number of elevators, screens, etc. The fine ore goes to the ore bins and roasters on the fifth level. Three straight-line roasting furnaces, hearths 12 feet by 100, capacity 75 tons apiece daily, prepare the ore for the 16 leaching tanks on the sixth level.

The roasted ore is stored in bins with 300 tons capacity, and is drawn from them into cars running above the leaching tanks. Each tank is 6½ feet deep, 22 feet square, and has a capacity of 110 tons of ore. Three tanks, in which the fresh solution is mixed and standardized, are located above the leaching tanks.

On the next level are the precipitating tanks where the values are recovered from the solutions. Two tanks 10 feet in diameter and 14 feet deep hold the gold solutions, the two precipitating tanks are 12 feet wide by 8 feet deep, and the filter presses are four in number with 36 sections apiece. The solutions that have been used run into a 24-foot sump tank 5 feet deep. Three steam pumps handle the solutions.

The refining of the precipitates is performed on the lowest level of the mill. Steel tanks, filters, and furnaces are provided for getting rid of the bases and producing bars of the precious metals. From the solution tanks, the tailings are flushed or shoveled out through gates in the bottom of the tanks.

The values are precipitated by means of zinc dust (brought from the flues of European zinc works). The solution is first agitated by introducing a current of compressed air, and on the addition of the zinc, precipitation takes place almost immediately. The excess of zinc and impurities is dissolved out by

sulphuric acid. The precipitate is passed through filter presses and the caked mass dried and fused in the ordinary way, the resulting gold averaging .900 fine.

The original capacity of the plant was 200 tons per day, but it was arranged so that it could be enlarged indefinitely without interfering with the steady working. After the completion of the plant six Griffin mills were installed. The buildings (which are of wood, whitewashed inside and painted outside, with roofs of corrugated iron), include an assay office, laboratory, store-rooms, blacksmith and machine shops. A large brick flue 435 feet long leads up to a steel stack 112 feet high near the top level of the mill. The wood used for fuel in the furnaces is brought in by a five mile flume. The main sources of ore supply have been the Ben Hur, Lone Pine-Surprise, San Poil and Blacktail mines, besides tailings from the old Pelatan-Clerici mill of the district.

THE MOUNTAIN LION MILL.

[The Mountain Lion Gold Mining Company.]

Automatic handling of the ore is one of the leading features of the Mountain Lion Mill at Republic. A self-dumping skip, operated by electricity, hoists the ore in the main shaft of the mine. Ore that fails to pass the grizzlies drops into a Blake crusher with a jaw 9 by 15 inches, then into a bin of 200 tons capacity. An automatic tramway 400 feet long carries the ore from the mine to the mill, where it is received in a bin of 500 tons capacity.

The batteries consist of 20 stamps of 1,200 pounds weight, which drop 8½ inches at the rate of 100 per minute; their rate of crushing is 100 tons per day to pass a 40 mesh screen. The coarse pulp, after running over amalgamated copper plates, is fed into 5-foot Huntington mills, one mill receiving the pulp from a battery of 5 stamps. When crushed to 80 mesh, it passes into steel leaching tanks, five in number, where it is agitated by propeller blades and leached for seven hours with cyanide solution, strength .5 per cent. The leached pulp passes from the leaching tanks into eight filtering tanks, each 6 feet deep and 24 feet in diameter. Further treatment is effected here by a solution of half the original strength, or .25 per cent., varying with the character of the ore, and requiring 24 hours time. In order to save cyanide solution, after the rich solution

has been drawn off from the filter tanks, the tailings are leached again; this solution is run into two sump tanks, and then back to two storage tanks where it is standardized again. Precipitation by means of zinc shavings takes place in two zinc boxes with sixteen compartments each.

The power plant consists of three Fraser and Chalmers boilers of 100 h. p., a Bates-Corliss and an Ide engine, 125 h. p. each, a 3-phase generator, 125 h. p., built by the General Electric Company, and two motors of 20 and 75 h. p. The surrounding region furnishes wood in abundance, and the water supply is drawn from Mud Lake, 2,000 feet south of the mill. Both mine and mill are lighted by electricity, which is also the power used for pumping, hoisting and milling.

III. STAMP MILLS (AMALGAMATION).

THE BLEWETT MILL.

[Chelan Mining Company.]

Blewett, in the center of the Peshastin mining district of Chelan county, is reached by wagon road from Leavenworth on the Great Northern Railway, 16 miles, or from Clealum on the Northern Pacific Railway, 32 miles distant. The Chelan Mining Company. of Seattle, now owns the stamp mill located at the mouth of Culver canyon, commonly known as the Blewett Mill, formerly owned by the Culver Company, and later by the Blewett Gold Mining Company. The ores treated are from the company's mines, as well as custom ores from the district at large.

The batteries consist of four sets of five stamps each, with Fraser and Chalmers automatic feeders, and double discharge, only single being used. 950 pound stamps, with chrome steel shoes and dies, drop 6½ inches at the rate of 90 per minute. The pulp is screened through diagonal slot screens, equivalent to 50 mesh, and falls on copper plates four feet wide and ten feet long, sloping 1½ inches per foot. The lower plates are silvered, 14 feet long, 4 feet wide, and falling two inches per

foot. Four Union tables receive the pulp, after which the slimes pass over canvas tables with a three inch fall. The canvas is swept four times in twenty-four hours, and the fines are saved in settling boxes. Under former management, the tailings carried values of several dollars, which ran into the creek. Outside parties becoming aware of this built a small cyanide plant with two tanks, having a capacity of about 10 tons per day, and thereby recovered a considerable amount of fine gold. The plant is no longer in use.

Wood is burned under two boilers (4 by 12 feet, used alternately), which furnish steam for a Corliss engine of 50 h. p. A flume 500 feet long brings water from the creek to a tank set 20 feet above the level of the stamp battery. A Hallidie aerial tramway with buckets holding 250 pounds each, carries the ore from the mine 4,000 feet distant and dumps it into two receiving bins of 400 tons capacity. The usual system prevails in regard to the different floors of the mill, the order here being, crusher, feeding bin, battery, and concentrating floors. Mention should also be made of the assay office and sampling room.

EUREKA MILL.

[Eureka Mining Company.]

The Eureka Mill is located just below the mine of the same name, in the Slate creek district, on the west side of the Cascade range, about 15 miles south of the international boundary.

The ore is brought from the mine by a tramway worked by gravity, and is crushed to 40 mesh by 10 stamps dropping 7 inches 104 times per minute. The free gold is saved on amalgamated copper plates, while the sulphides, with small amounts of sylvanite, are concentrated on two Wilfley tables. The slimes are treated on canvas blanket tables.

MAMMOTH MILL.

[Mammoth Gold Mining Company.]

This five-stamp mill, located at Barron, receives ore from the mine by an aerial tramway. A partial saving of values has been effected by amalgamation and concentration, but other machinery better suited to the ore will be required.

STAMP MILLS IN THE PALMER MOUNTAIN DISTRICT.

Black Bear Mill, five stamps with concentrator, run by water-power. Located at Loomis, to treat ore from the Black Bear mine, two miles distant on Palmer mountain.

Ivanhoe Mill, at mine on Palmer mountain. A ten-ton mill with Dodge pulverizer, amalgamating plates, concentrator and slime tables.

At Triune mine, near Golden, a ten-stamp mill with four Frue vanners, operated by steam power.

On Wannicutt lake, a ten-stamp mill which treats ore from the Spokane mine, one mile distant.

MT. BAKER MILL.

[Mount Baker Mining Company.]

A ten-stamp mill is being completed this spring, 1902, to treat ore from the Lone Jack ledge. As the mine is at an elevation of 6,000 feet, an aerial tramway will probably be found the cheapest method of hauling to the mill, 4000 feet lower. It is expected that amalgamation will give a high percentage of the assay value of the ore, but there are tellurides present, which will be saved on concentrating tables.

GREAT EXCELSIOR MILL.

[The Great Excelsior Mining Company.]

The present equipment comprises a five-stamp battery and a Parker rotary four-stamp mill; 50 additional stamps have been ordered, along with New Standard concentrating tables.

IV. ARRASTRAS.

Throughout Washington and especially in the Cascade range, in regions remote from the railway, the traveler frequently finds arrastras, sometimes in operation, more often idle, and many of them out of repair. Without doubt two reasons for the popularity of the arrastra, particularly for use in prospecting this region, are the abundance of suitable rock which can easily be trimmed into shape for lining the pit and making drags that

wear well, and the presence of numerous streams which furnish convenient water power. With increase of depth in the mines and lack of free-milling ores, the arrastras are abandoned.

SWAUK CREEK DISTRICT.

Several arrastras are found on Swauk creek near Liberty. Water power is used exclusively. In one case a large overshot wheel runs two arrastras and a two-stamp mill. Usually horizontal wheels are used, geared to a revolving center post with arms which drag four grinding blocks, the ore being fed in egg-size.

PESHASTIN DISTRICT.

On Peshastin creek, near Blewett, three arrastras have been in recent use, and the remains of several old ones indicate that prospects in the district have been tested by this method for many years. Whether other forms of treatment would yield greater values from the same ores is still an open question.

The present arrastras are from three to twelve feet in diameter and about three feet deep, built of the most suitable pieces of stone to be found at hand. The favorite source of power is a horizontal water-wheel, run by the force of impact of a stream of water shooting out several feet from the end of a flume. The wheels are from sixteen to twenty-four feet in diameter, and sometimes attain a speed of eighteen revolutions per minute. The drag-blocks consist of granite boulders (weighing half a ton or more when new), which are fastened to the revolving arms of the mill by means of chains. From one to three thousand pounds per day is the crushing capacity.

SLATE CREEK DISTRICT.

The form of the arrastras on Slate creek does not differ greatly from that used elsewhere. Many of them have been running intermittently from the earliest days of the district.

IV. CONCENTRATORS AND COMBINATION PLANTS.

THE WAUCONDA MILL.

[Wauconda Gold Mining Company.]

BY A. J. EDWARDS.

Prominent among the mills employing combination processes is that of the Wauconda Gold Mining Company, whose main property is situated at the town of Wauconda, Okanogan county. A sixty-ton mill, to treat the Wauconda ores by the Rossman process of pan amalgamation, was erected during the fall of 1901, under the superintendence of officers of the Rossman Company, of Minneapolis. The mode of treatment consists of coarse crushing by stamps, further reduction in a pulverizer, coarse concentration, and pan amalgamation of concentrates.

The ore is crushed by a Gates gyratory crusher in the sampling mill at the tunnel mouth, and is conveyed by tramway to the ore bins at the mill, 800 feet distant. The main mill building is 50 feet in width by 70 feet in length, built in six benches. On the top bench is the engine and boiler plant (capable of furnishing 70 h. p.), and also the dynamo for lighting the company's buildings and the mine. The next bench contains the batteries—a five-stamp battery of latest design from the Allis-Chalmers Company, and a two-stamp battery, both automatically fed by Challenge feeders. The third and fourth benches contain the two revolving pulverizers, two concentrators, and ten amalgamation pans, all of the Rossman type. Three Rossman settlers and the tailings sluices occupy the two lower benches. Advantage is taken of a convenient hill slope to permit of using gravity to a great extent, and unlimited ground is left for tailings.

The ore passes through batteries and the pulverizers, and from thence into the concentrating pans. These, like much of the other machinery, are of the Rossman design and introduce new features for the work. It is sufficient to say of them that while the pulp is held suspended in water in the pans, the lighter portion, including the worthless gangue, is allowed to flow away and the heavier portions are retained. This method does not appear to allow of an extremely close concentration, the Wauconda

ores being concentrated only from six or eight to one, but it is an exceedingly simple and inexpensive operation. The percentage of values remaining in the tailings is low, and the process accomplishes very effectually the object of reducing the quantity of pulp which the pan must treat, and consequently increases the capacity of the mill to a considerable extent.

After this operation the concentrated pulp is elevated by a Frenier pump to hoppers, where the excess water is removed and returned for use again in the batteries, while the thickened pulp is charged from the hoppers with the chemicals and mercury into the amalgamating pans. The object of the chemicals is to assist in freeing the gold from any substance rendering it refractory, so that it will readily amalgamate. The Rossman pans differ from other pans in various particulars of form, and these differences effect a radical increase of efficiency. The pans are somewhat smaller than usual and are charged with from 250 to 350 pounds of pulp at once. The time employed is only about 30 minutes for a charge, so that the ability to thoroughly amalgamate in such a short time more than compensates for the small charge. When amalgamation in the pans is complete, the pulp passes to the settlers, where the mercury amalgam is separated and the tailings sent to the dump. The mercury is retorted as usual. Every effort has been made in designing the mill to make the operating as nearly automatic as possible, so that the labor required will be reduced to a minimum.

The sampling mill at the tunnel mouth contains a machine shop which is fitted with a large iron lathe, power drill, emery wheels, wood saws and blacksmith forge. A Root blower, for ventilating the mine, and a Gates ore crusher are also in this building. The sampling mill portion is fitted with a complete set of Rossman machines, including rolls, pulverizer, amalgamating pans and settler. These are similar in design to those in the big mill but of reduced size, the diameter of the pans being 24 inches, while the regular pans are 36 inches. Charges of 50 to 70 pounds of ore can be treated in these pans, making it possible to carry out complete tests of the ore, both as to values and methods of treating, as the work progresses.

Since the sampling mill was opened, in October 1901, a number of large samples of Wauconda ore have been worked, usually 50 pounds at a time. During the early part of December, the

work on the big mill was so far advanced that a good sized preliminary run was made. It is expected that the mill will be in continuous operation by the beginning of spring. The work which the two mills have already done makes it possible, however, to speak with considerable certainty as to the adaptability of the method selected for treating the Wauconda ore and its success in so doing. The numerous 50 pound samples worked in the sampling mill gave values of from $10 to $18 per ton and the values remaining in the tailings ranged from only fifty cents to $1 per ton, indicating a very uniform saving of about 95 per cent. The tailings of the preliminary run in the big mill indicated a similar large per cent. of recovery. The average value of the ore as shown by all these samples taken from the different drifts in the mine and from general averages of the dump was about $12. The results from treating the concentrates in the amalgamating pans were equally satisfactory, showing that a most efficient system has been chosen.

The low cost of treatment by this method, about $1 in excess of cost of free milling under similar conditions, is another important consideration. Much fuller information will of course be available as to the efficiency with which the Wauconda ore can be treated after the mill has been in operation for a month or so.

GOLDEN ZONE CONCENTRATOR.

[Golden Zone Mining Company.]

The concentrating and amalgamating plant of the Golden Zone Mining Company is situated in the Palmer Mountain district, sixteen miles north of Loomis, and three miles south of the British Columbia line.

Ore is brought from the mine by a wire ropeway of 1,100 feet single span, and an incline 600 feet long. Power is furnished by a 50 h. p. engine and boiler. The ore is crushed in two sets of Cornish rolls and a Huntington mill, and amalgamated on copper plates arranged in three steps. A single hydraulic classifier and three Wilfley tables reduce thirty tons of ore per day to two tons of concentrates, carrying about $200 in gold. Since the mill began work, early in 1900, about 100,000 tons of ore have been handled. The concentrates are shipped to the smelting works at Tacoma and Everett.

RUBY CONCENTRATOR.

[Washington Reduction Company.]

Although no work has been done in the line of silver-lead concentrating in the district about Ruby since the fall of silver in 1893, the complete concentrating plant at Ruby deserves mention on account of the work done before that time.

An aerial tramway, run by gravity, brought ore from the First Thought mine, one mile distant. Beginning at the mine, the tramway runs up over a ridge, then descends by a long slope to the mill, the relative grades being such that the greater weight of the loaded buckets on the mill-side served to keep the endless cable in motion. Electricity, generated by water power, ran the milling machinery, which consists of two rock crushers, two Dodge pulverizers with screens, and eight Frue vanners. The slimes were run over canvas strakes. During the few months that the mill was in operation it produced $40,000 in concentrates.

OLD DOMINION CONCENTRATOR.

[Old Dominion Mining Company.]

Another silver-lead mill which has been lying idle for some time, is that of the Old Dominion mine, one of the best developed and most productive mines in the Colville district, having yielded about $2,000,000 in silver, lead and gold.

The mine tramways from two different levels are carried out by trestlework over the edge of a smooth hill slope below the tunnel mouth. The mine ore is dumped into a steep chute 80 feet long leading down to the crushing floor of the mill. After passing over grizzlies and undergoing preliminary crushing and sizing in rolls, the ore travels by gravity to the concentrating floors where the jigs and slime tables are placed. The mill is run by steam power, with wood fuel.

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WASHINGTON

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HENRY LANDES, STATE GEOLOGIST.

VOLUME I.

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IN SIX PARTS.

PART III.

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PREFACE.

In this article on the NON-METALLIFEROUS RESOURCES OF WASHINGTON, EXCEPT COAL, a brief discussion is had of six mineral products, viz.: building and ornamental stones, clay materials, limestone, soils, road-making materials, and petroleum.

In the few pages devoted to building and ornamental stones, some reference is made to the geographical distribution of these products, and the best developed quarries are hastily described. While the building and ornamental stones of the state are of great importance, but scant attention is given them in this report because it is planned that they shall be the subject of an extended and exhaustive article in the report for 1902.

While clay is an important resource, the matter pertaining to it is chiefly limited to descriptions of a few of the leading plants concerned in the manufacture of clay products. As in the case of building stone a complete account of the clay resources of the state will be given in the next annual report.

Limestone for lime-making is one of the state's leading mineral resources. Large deposits of excellent limestone occur at many places in Washington. The lime-burning industry is already well developed, and at the present time large quantities of lime are exported from Washington to all the neighboring states, to California and to Hawaii.

Soils come under the head of non-metalliferous, or mineral resources, because they are derived directly from rocks. In this article soils are treated from the geological standpoint, and the close connections between the rock formations and the different varieties of soils is shown.

Road-making materials are valuable resources wherever they occur, and Washington is fortunate in possessing throughout the state road metals of superior quality. Road construction on the most scientifia basis is receiving a great deal of attention now-a-days in the older states, and Washington with her splendid materials should be a leader in the grand movement toward good roads.

Petroleum, at the present time, is not one of the state's determined mineral resources. The subject receives some consideration in this report because of the wide-spread interest in oil prospecting, and because of the many inquiries as to whether or not there is any possibility of oil being found in different parts of the state. There are some parts of Washington where the correspondence in age, composition and structure between the rocks here and those of the oil-bearing districts of California is very striking. In such localities of the state, especially where there are good surface indications, prospecting for oil may be looked upon as well worth the while.

THE STATE CAPITOL, CONSTRUCTED OF CHUCKANUT AND TENINO SANDSTONE.

THE NON-METALLIFEROUS RESOURCES OF WASHINGTON.

BUILDING AND ORNAMENTAL STONES.

INTRODUCTION.

In order to be valuable for building purposes a stone must possess strength and durability and be of a pleasing color. In addition to these qualifications, it must be accessible to market. It must also be of such a nature that it can be worked into the proper shape without an undue amount of labor.

In regard to the first qualification, that of strength, its importance is usually overrated. Most stone is sufficiently strong to withstand the weight of any ordinary building, and it is only when the stone is required for heavy masonry construction that its crushing strength needs to be carefully considered.

The durability of a stone is a much more important factor. Buildings which are constructed of stone are presumably built to last, and careful attention should therefore be given to the durability of the material. Stones of different kinds are variously affected by the atmosphere. Sandstones which are composed mainly of quartz grains are affected according to the character of the cementing material. If the cement which binds the grains together is easily leached out by water the stone quickly crumbles away, but if the grains are bound together with silica or some other insoluble material the stone is very durable.

Granitic rocks and nearly all of the finer grained igneous rocks make very durable building stones. Gneiss and schist are apt to scale off along their bedding planes and when they are used in building should always be laid on their flat side, and never on edge. The same rule applies to all stones that show any signs of bedding.

Serpentine, while rather a soft rock, seems to be little affected

in color and more suitable for building purposes are found in a number of places in the Cascade and Olympic mountains, but have not yet been utilized. Serpentine, valuable for building and ornamental purposes, is extensively quarried at only one place, viz., Valley, Stevens county.

GRANITE QUARRIES.

Index.

The Index granite works, owned by Mr. J. A. Soderberg, have for the last ten years enjoyed a practical monopoly of the granite business in the Puget sound region, except for the finer varieties used in monumental work. Large quantities of this granite have been used for street curbing, monument bases, foundation work for buildings, and many other purposes. It is a light gray biotite-bearing hornblende granite with crystals of orthoclase and plagioclase feldspar. The great preponderance of feldspar over quartz carries the rock near to the border line of syenite. It makes a strong, substantial building stone but will not take a good polish. It occurs in inexhaustible quantities in the country about Index, the whole core of the mountain being made of it. The quarry is located alongside of the railway track, about half a mile west of the railway station at Index. The rock is blasted loose with black powder and split up into blocks by means of plug and feather drills. Cars are run on the side track and the blocks of stone are loaded by means of derricks. The number of men employed varies with the number of orders on hand. During the summer of 1901 about forty men were employed continually.

About one-half mile east of Index a new granite quarry has been opened lately by Mr. T. S. Ellis, of Seattle. It is very similar to the Soderberg stone, but is a little brighter in appearance. It is being used for the piers of the new Arcade building at the corner of Second avenue and Marion streets, Seattle. It is also being used for monument bases by some of the marble companies in Seattle. The demand for granite in western Washington is increasing very fast, and there is no doubt but that both of these Index quarries will soon be developed on a much larger scale. They are very favorably located with regard to the railroad, and the stone is so situated that it can be quarried at a minimum expense.

Spokane.

Spokane is very favorably situated with regard to building stones. There are several granite quarries very near the city which are worked as occasion requires. At the present time, however, none of the quarries are being worked continuously. In the quarries east of the city the stone is taken out by contractors who only aim to fill their standing orders, and who do not keep a supply on hand or do any work when there are no orders ahead. The stone varies slightly in texture, but is mostly a very light gray muscovite-biotite granite with large crystals of feldspar. One of the quarries belonging to the Washington Monumental Company is in a dark gray biotite-hornblende gneiss, closely banded. The stone is used largely for street curbing, monument bases, and copings for building purposes.

Medical Lake.

The quarry at Medical Lake, about sixteen miles southwest of Spokane, is in granite very similar to that found about Spokane. It is located on an outcropping of granite surrounded on all sides by basaltic lava, being one of the few places within the lava field where the older rocks crop out on the surface. The quarry has been in operation for a number of years. Most of the product goes to Spokane and surrounding towns. Some of it has been shipped as far west as Seattle where it was used in the Administration building of the State University.

Snake River.

The Snake River Granite Quarry, belonging to Mr. Miles C. Moore, of Walla Walla, is located on a ledge of granite at the bottom of Snake river canyon at a point where the river has carved its way through the basalt and laid bare the older formation. The quarry is situated in Whitman county, about twenty miles below Lewiston, in township 13 N., R. 43 E. The rock occurs on both sides of the river and is capped by basalt probably a thousand feet in thickness. A recently constructed branch line of the Oregon Railway and Navigation Company runs directly through the quarry. Before the railroad was built the river steamers landed alonside and the stone was hoisted aboard by means of derricks and carried down the river forty miles to Riparia, where it was transferred to the O. R. & N. Railway.

The stone is a light gray biotite-hornblende granite with large crystals of clear othoclase feldspar. It is very hard and unweathered and makes a handsome and durable building stone. About fifty thousand cubic feet of it was used in the new Government building at Portland, Oregon. The piers and buttresses of the Northern Pacific bridge at the mouth of the Snake are also constructed of this stone. It is used largely for street curbing in Spokane, Portland, Walla Walla, and other cities.

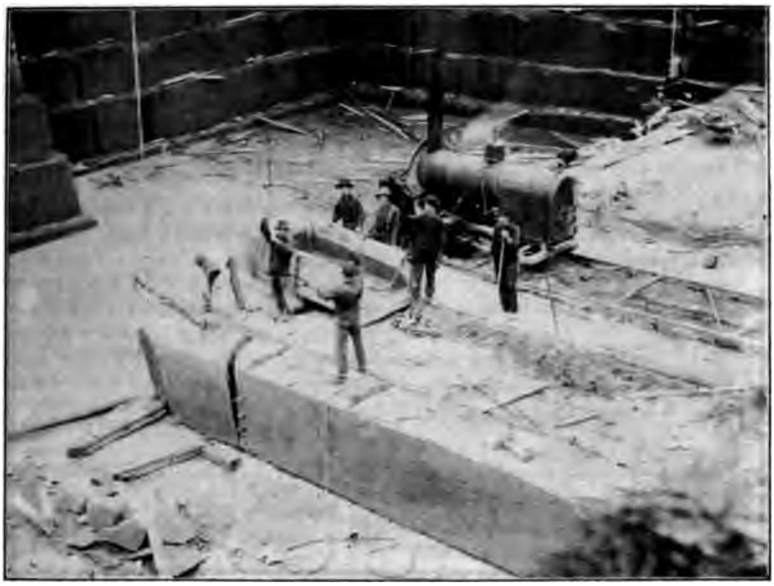
Farther up the Snake than the locality last mentioned, near the mouth of the Grand Ronde river, Mr. Moore has another granite quarry, but which is not as accessible as the first one. The stone is a dark gray hornblende-biotite granite, rather fine grained. It takes a beautiful polish and has been used to some extent for monumental work, for which purpose it is admirably suited. Some of it has been brought down to Lewiston on scows and from there re-shipped by steamers. Navigation on the upper Snake is very precarious and until better shipping facilities are obtained the quarry will be rather handicapped. Steamers have at times of high water ascended the river to points above this quarry, but for practical purposes the head of navigation of the Snake seems to be at Asotin.

SANDSTONE QUARRIES.

Chuckanut.

The Chuckanut quarry is situated on Chuckanut bay, about five miles south of Whatcom. The stone is a bluish sandstone very similar in appearance to that of the Tenino quarry, but is considerably harder. Like all sandstones of this class it hardens on exposure to the atmosphere so that in buildings like the Dexter Horton bank building of Seattle, where it has been in position for a number of years, it is now very hard. A compression test made at the Watertown arsenal, Massachusetts, gave an average crushing strength of 11,389 pounds to the square inch. This strength is sufficient for all of the weight that will ever be brought to bear upon the stone even in the largest buildings.

The stone occurs in a high bluff overlooking the bay and the beds pitch towards the bay at a steep angle. As the rock is blasted loose it flakes off along the bedding planes and is allowed to slide down to the bottom of the slope. When required for dimension stone the large blocks are loaded onto trucks and



TENINO SANDSTONE QUARRY.

MILL FOR SAWING STONE, TENINO SANDSTONE QUARRY.

run into the mill where they are sawed into the required sizes by sets of gang saws. The mill is supplied with two sets of gang saws, and is run by steam power. A half dozen or more slabs are sawed at the same time, the number depending upon the thickness. The sawing is so arranged that when the stone is put into a building the bedding planes shall lie flat. Most of the orders call for sawed stone of specified size.

The quarry was first opened up by Mr. Henry Roeder. He began operations at a point a short distance south of the present workings in the early seventies and moved to the present location at a much later date.

The following are a few of the important buildings constructed wholly or in part of this stone: U. S. custom house, Port Townsend; U. S. custom house, Portland, Oregon; court house building, Port Townsend; Dexter Horton building, Seattle; new high school building, Seattle; Thurston county court house, now the state capitol, Olympia.

Sucia Island.

On Sucia island, the most northern one of the San Juan group, a quarry was opened some years ago in a dark brown sandstone of Cretaceous age. The quarry is located on the water's edge so that deep water vessels may land alongside and the stone hoisted by derrick from the quarry to the deck of the vessel.

The stone is a hard, massive sandstone of such very coarse texture that it approaches a grit. It is not an easy stone to work and is probably more suitable for heavy masonry work than for ordinary building purposes. The United States drydock at Port Orchard was constructed of stone from this quarry.

Tenino.

By Milnor Roberts.

At a number of points in the neighborhood of Tenino, fifteen miles southeast of Olympia, the Eocene sandstone has been quarried as a building stone for a number of years. In some of the pits that have been opened, while the stone is of excellent quality in small masses, it occurs interbedded with thin layers of shale or lines of very hard concretions, which reduce or completely destroy its commercial value. Coal is found near by in the same geological horizon.

The only quarries in this region that are being worked at present are in a group at Tenino, controlled by Messrs. Russell and Fenton. Stone was first taken out in 1889, since which time the output has been practically continuous, amounting to a gross total of one and one-third million cubic feet. As almost every cubic foot of the stone is of a quality fit for the market and the waste in handling is slight, the yield of the quarries to date is seen to have been considerable. It is impossible to say what are the limits within which stone of the same lithological character may be found, since prospecting and development alone can prove that, but the indications are that it occurs in abundance.

The stone is a rather fine-grained sandstone, light greenish gray in color, free from inclusions and of an even texture. The composition is given as follows:

Silica	74.00 per cent.	Oxide of Iron	6.65 per cent.
Alumina	13.51 per cent.	Calcium oxide	3.61 per cent.
Magnesium oxide	1.65 per cent.	Sulphur trioxide	none.
Phosporous pentoxide	none.		

A sample was tested by the ordnance department of the United States army at the Watertown arsenal July 3, 1893—compression test No. 9256. The first crack occurred under 173,000 pounds pressure, and the ultimate strength was found to be 176,100 pounds, or 6,879 pounds per square inch. Under the microscope the rock shows a large proportion of well-rounded grains of white quartz, about one-tenth of a millimeter in diameter. There are some dark colored grains of quartz present, along with crystals of muscovite, biotite, hornblende, and other minerals. A tendency to exhibit a banded structure is apparent, but it is more noticeable in large masses in the quarry than in a block or hand specimen. The bands seem to be due to layers of finer and darker colored material, and represent the bedding planes of deposition. The dip is about 15 degrees, pointing a few degrees west of south.

Two main quarries have been opened up in the north side of a hill, half a mile northeast of the station of Tenino, on the Northern Pacific Railway (from which a spur enters the yards). The larger pit, used as a reservoir at present, extends 225 feet along the hillside, is over 100 feet wide, 50 feet deep at the back, and 25 feet deep in front, the difference being due to the slope of the surface. The newer pit, a few steps distant to the north-

west, is 180 feet long east and west, 85 feet wide and about 30 feet deep. A swinging crane with 70-foot boom stands on the edge of this pit in the middle of the south side.

The stone is cut out by two steam channelers into blocks four and one-half feet thick. A line of track made in permanent sections is laid along the floor close to the wall. The channeler, which carries its own boiler and engine, moves back and forth on the track for a distance of twenty feet, while the chisels work in vertical grooves with a steady stream of water running in. Ten or twelve cuts are needed to reach a depth of 54 inches, occupying from half an hour to an hour's time. When grooves have been cut along the whole length of track, the channeler is lifted by the crane and the track relaid for a parallel line of cuts. Other grooves are cut similarly at right angles to these, then the blocks are loosened by wedges driven in at the bottom. The crane hoists the blocks out of the pit, and places them on a small flat car, turning them on edge if they are to be cut by the gang saws. This is done in order that the sawn blocks when used in masonry shall lie in the same relative position as in the quarry.

The gang saws are four in number, carrying from one to eight saws apiece. Each saw is simply a flat piece of steel, ten feet long, five inches wide and three-sixteenths of an inch thick, without teeth, and depending for its cutting power upon the speed with which it runs, and upon an abrasive in the form of coarse steel filings, fed with water into the cut. The saws are set on edge, parallel, to cut downwards, and are bolted at the ends like a bucksaw, the distance separating any two saws determining the thickness of the slab. The rectangular frame that holds them is swung from a shaft placed at right angles to the line of cut. The shaft may be raised or lowered by means of a positive feed gear. The gangsaw is driven by a rod connected directly with the piston of a steam cylinder. The limit of speed in cutting depends upon the rate at which the saws may be forced down against the stone without buckling. An average of more than one foot per hour is usual, but with plenty of steam and careful feeding of the steel filings, a speed of two feet may be attained.

That the sawing is not the most expensive part of the quarryman's work may be judged from the fact that slabs one foot thick sell at the rate of 45 cents per superficial foot, eight inches

thick at 35 cents, four inches thick at 20 cents, and two-inch slabs at 16 cents per square foot of surface. When large quantities of a certain sized stone are ordered it may be produced much cheaper than this. It is the custom here, as elsewhere, to cut stone at the quarry to the proper size ready for placing in the building, mainly to save freight on waste material. About thirty or forty men are employed, the number depending on the orders at hand.

The Tenino sandstone has been used in many large buildings throughout the state and in Oregon and California, both as the principal material of construction and as a finishing stone. The State capitol now under construction, the Bailey building in Seattle, Calvary Presbyterian Church in San Francisco, and several business blocks in coast cities may be cited as examples. The stone seems to harden on exposure and wears well. Its refractory nature is proved by its continued use under boilers and as a lining for open fireplaces. Other uses to which it has been put with satisfactory results are as an ornamental stone for fountains, monuments and mantels, and in the shape of rubble or quarry waste to form concrete.

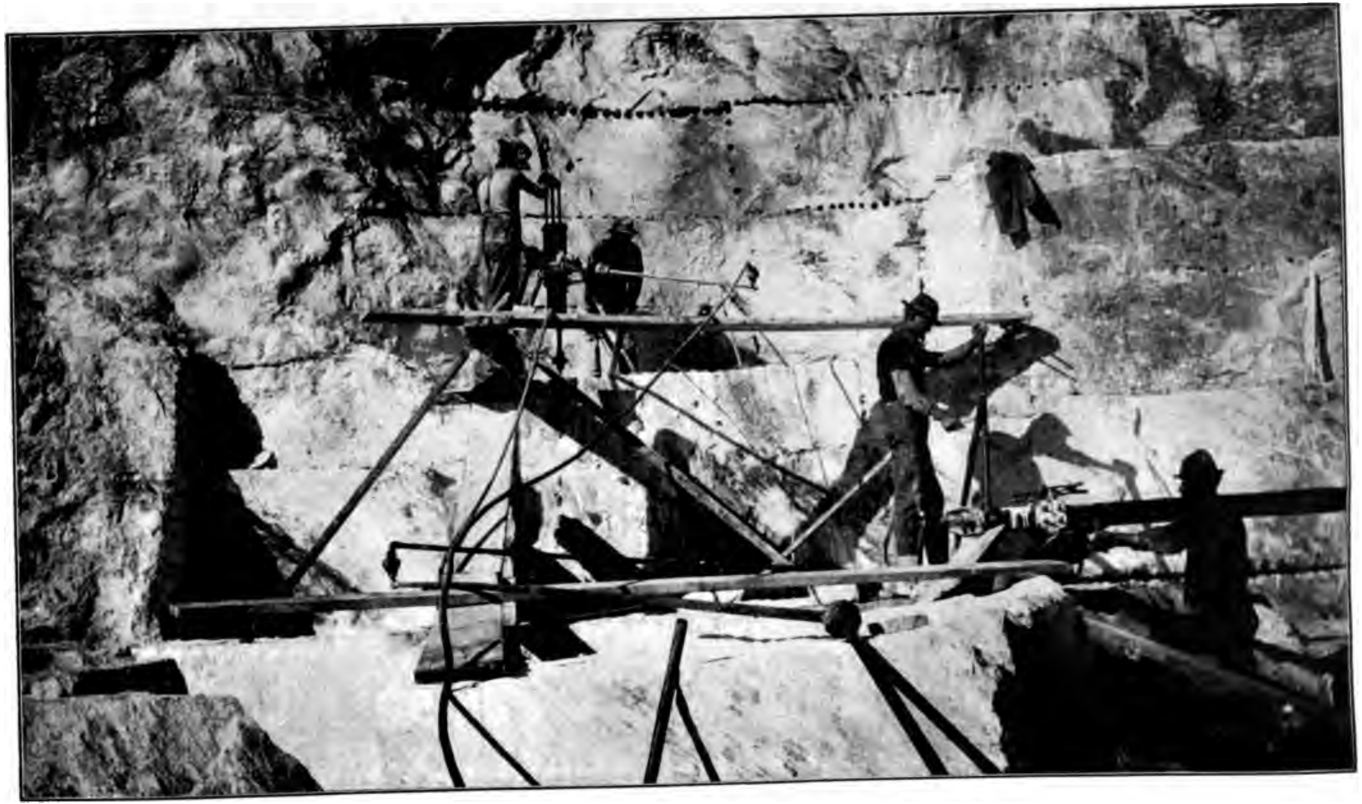
Wilkeson.

The Wilkeson quarry is the property of the Northern Pacific Railway Company and is situated at the town of Wilkeson, Pierce county. The rock is a sandstone belonging to the coal series. It is bluish-gray in color and is streaked with brown iron rust and carbonaceous matter. When found free from these defects it has a fresh pleasing appearance and makes a hard, substantial building stone, but it is difficult to get a large quantity of it that is uniform in color and texture. The quarry has not been in active operation for the last seven or eight years. Occasionally the railway company quarries some of the stone for its own use, but does not place any of it on the market.

SERPENTINE QUARRIES.

Valley.

The United States Marble Company, of Spokane, is operating a serpentine quarry near Valley, about fifty miles north of Spokane, on the line of the Spokane Falls & Northern Railway. It is the largest quarry in the state, both in the number of men



QUARRY OF U. S. MARBLE COMPANY, VALLEY

employed and in the value of the output. It is comparatively a new concern, only having been in active operation since July, 1898, but they have already spent $75,000 in developing the property and in equiping the plant. The property consists of a compact group of eighteen claims on Greenway mountain, including the serpentine dike upon which the quarry is located; also eighty acres of marble land within a mile of the railroad, upon which no work has yet been done except a little surface prospecting. The dike of serpentine lies between a foot wall of black marble and a hanging wall of silver gray slate, both valuable, but neither of which are being worked at present. The dike, which is about six hundred feet wide, has been traced in length a distance of fifteen hundred feet and has a known depth of seven hundred feet. It varies in color from light gray to deep green, the green being the most valuable. The company has given to the latter the name Royal Washington serpentine. Three machine drills are now at work in the quarry and as soon as the installation of the new power plant is completed the number of drills will be increased to eight. No powder of any kind is used in quarrying, as the stone is too valuable to allow any of it to be shattered by blasting. It is quarried out in as large blocks as can be readily handled by team, and hauled to the mill which is situated at the base of the mountain. The company claim that they can quarry out blocks of the Royal Washington of fifty tons weight, if necessary. After the blocks are quarried they are loaded on a wagon by means of a derrick and taken to the mill. The mill is equipped with the very latest machinery for sawing, grinding and polishing the stone into any desired shape. There are two sets of gang saws, a rubbing bed thirteen and a half feet in diameter, three polishing machines, four lathes, and a number of other pieces of machinery.

The camp, consisting of bunk house, kitchen, office, barns, store building, etc., is situated on the mountain side several hundred feet below the quarry. The general store not only supplies the company's own employees, but also does considerable business with the nearby mining camps. A warehouse has been built at Valley, where the finished stone is stored awaiting ship ment.

Since the fall of 1900 the mill and quarry have been operating night and day continually in an effort to keep up with the

orders. Many orders in fact have had to be refused until larger machinery could be installed. There are now over eighty men on the company's pay roll and they are working on orders for several months ahead. Most of the orders are for monumental and building stone, both for interior and exterior finish.

At the Pan-American Exposition at Buffalo the company exhibited a beautiful mantle showing the various colors and qualities of their stone. The exhibit was awarded a silver medal.

The marble and slate deposits which up to the present time have been entirely untouched offer a promising field for future activity. The present limited demand for these two stones can be largely increased and the company is now making preparations to open up these deposits and put the products on the market.

MARBLE QUARRIES.

Stevens County.

At a number of places in Stevens county marble of an excellent quality and of a very pleasing color is found. Blocks of large size may be quarried, and a monumental stone of superior excellence obtained. In some instances the marble lies convenient to the railway so that the quarry products may be easily shipped to market. A great deal of interest is now being taken in these marble deposits and it is expected that a number of large quarries will soon be put in operation.

The marble of Stevens county belongs to the ancient rocks now so highly metamorphosed that they have become quite crystalline. Such rocks are characteristic of the northern Cascades and the Okanogan highlands, extending eastward to the Idaho line. The marble occurs in occasional masses among the granites, gneisses, and schists wherever erosion has not yet removed it.

NEW QUARRY LEVEL, U. S. MARBLE COMPANY, VALLEY.

QUARRY OF U. S. MARBLE COMPANY, VALLEY.

CLAY MATERIALS.

INTRODUCTION.

The clays which are being used in the state in the manufacture of different varieties of brick, drain tile, sewer pipe, terra cotta products, etc., belong to several different geological formations. The most important clay deposits may be divided according to their method of occurrence into glacial clays, residual clays, and clay shales.

Glacial clays are found very generally distributed over all of the glaciated region of western Washington. They are composed of the fine flour ground up by the glacial ice and deposited by streams in the numerous small lakes and ponds which abounded throughout the region during the time when the ice was disappearing. The clay beds occur very irregularly, interstratified with sands and gravels or embedded in the till, and the quantity in any one place is largely a matter of speculation. The brick yards which utilize this clay are all located either on the shores of the Sound or on railway lines close to the larger centers of population. The clay is used chiefly in the manufacture of common red brick, and this industry has grown to be one of considerable magnitude. During the year 1901 the brick yards of Seattle alone made over thirty-nine million red brick, having a total value of nearly $400,000.

Residual clay is found only in the non-glaciated parts of the state. It is the residue left after all the soluble parts of a rock have been carried away. In western Washington, between Puget sound and the Columbia river, this clay is very thick in places, being formed largely by the weathering of shale. Shale is merely consolidated clay, so that the line of distinction between them is not very clearly drawn. Occasionally the clay beds are not very deep, and graduate insensibly into the solid shale beneath.

In eastern Washington the fine residue left by the decomposition of basalt makes a very good red brick. Throughout most of the region where the basalt occurs the brick that is used is made from this material. Small kilns are in operation in a number of places to supply the local demand.

The more expensive products, such as cream-colored pressed brick, red pressed brick, vitrified brick, drain and sewer pipe, and terra cotta articles are all manufactured from the older shales and clays which are described in connection with the different manufacturing plants which use them.

DENNY CLAY COMPANY.

By Milnor Roberts.

The clays used by the Denny Clay Company, of Seattle, are all obtained from the company's mines at Kummer and Taylor on the Columbia & Puget Sound Railroad. At Kummer, in Green river canyon, the variety known as "flint" clay is mined from a seven-foot vein at the foot of an incline 700 feet long. The clay used for making sewer pipe occurs in a mass 60 feet thick, which is treated just as a coal bed would be, and mined by breasts. A tunnel has been driven in at a point 20 feet above the high water mark of Green river. On account of the strength of the clay wide breasts and small pillars have been found safe to use. At Taylor, 20 miles to the northeast, the quality of the clay renders it suitable for making pressed brick, flue lining and terra cotta.

George W. Kummer, general manager of the company, who has been experimenting here for a dozen years past, and is familiar with Eastern methods of manufacture, has found that unlimited combinations can be made out of these clays, to produce practically all forms of brick, pipe and fire-proofing material. For instance, the highly refractory but non-plastic "flint" from Kummer, when mixed with a proper proportion of the Taylor clays, makes a highly refractory yet strong fire brick. Again, as a matter of experiment, pressed brick for facing buildings has been produced in twenty-three distinct shades of color, from the seven different kinds of clay at hand. Doubtless in some of these cases the result has been due to skillful handling in the kiln, varying the degree of heat, muffling, using direct fire or radiated heat. In burning a kiln full of brick it is unusual to find absolute uniformity of color throughout, as different conditions may prevail in different parts of the kiln, and for similar reasons it is difficult to match a peculiar color with exactness.

In the following analyses, made by W. J. Rattle, of Cleve-

land, No. 1 is the flint clay from Kummer, Nos. 2 and 3 are from Taylor, and No. 4 is a fine sand from Kummer which is mixed with clays to increase their percentage of silica, and add solidity to the brick.

COMPONENT PARTS.	*No. 1*	*No. 2*	*No. 3*	*No. 4 Fire sand*
Silica	83.44	41.86	72.80	78.60
Alumina	45.28	40.49	19.95	18.08
Lime	1.60	.62	.52	1.22
Magnesia	8.61	Trace	Trace	.648
Iron peroxide	1.57	....	....	2.29
Iron sesqui oxide	....	.71	.71	.114
Alkalies	1.44	....	.114	....
Soda and potash	....	1.47	2.98	....
Common water	16.44	15.29	8.50	8.80

The works of the Denny Clay Company are situated one mile southeast of Georgetown, and six miles from the center of Seattle on the line of the Northern Pacific Railway and the electric line to Tacoma now in process of construction.

Clay arriving by car from the mines is piled under sheds, each class by itself. Certain combinations of clays being required for certain products, the mixing is done by taking the proper number of loads by wheelbarrow from each pile and feeding them together into the crushing pan. Coarse lumps are first broken in a jaw-crusher, from which an endless belt carries the broken material to the pan. The latter is a form of Chilian mill, consisting of a circular steel pan nine feet in diameter, with flat bottom and vertical sides eighteen inches high. Power furnished to a central column with bevel gearing causes the pan to turn at the rate of 25 to 30 revolutions per minute. Two steel-tired grinding wheels, four feet in diameter and eight inches thick, rest vertically on the bottom of the pan and turn on a horizontal axis which is hung on springs. The outer edge of the pan bottom for a width of two feet is a screen surface, with slotted openings one-fourth inch by two and one-half inches, radiating from the center. The clay is both crushed and ground by the rollers, and forced to the outer edge of the pan, where the fines fall through the screen to a lower plate and are discharged into an elevator. Stationary steel guides set in the pan shunt the contents in toward the center at every turn, thus bringing back under the grinding wheels all material that fails to pass the screen.

The elevators used for clay are canvas and rubber belts with

paddles attached, running in a trough. From the grinding pan the fines are carried up to the third floor and run through a trommel. The coarse is allowed to run back over a long screen, returning to the grinding pan. The size of the mesh used in the trommel and screens depends altogether on the purpose for which the clay is needed, but ordinarily it varies from ten to twenty holes per linear inch. Screened clay falls through a chute to the mixing or "wet" pans, two in number, placed side by side and handled by one man. The apparently simple work of tempering the clay by mixing with water, in reality requires great experience in handling clays, and a knowledge of their physical properties, especially their plasticity, therefore the man who fills the position of mixer is more responsible than anyone else for the burning and wearing qualities of the product. The pans are similar in construction to the grinding pan, but as there is no outlet for the mixture through the bottom, a long-handled scoop set on a pivot is used to raise the tempered clay and dump it into an elevator.

The main building in which the brick and pipe presses are placed measures 80 by 150 feet and is three stories high. A complete heating plant with steam radiator pipes under the first floor keeps the air in the building at the proper temperature for drying green material. The engine and boiler plant in an adjoining building generates 300 nominal horse power. In order that the buildings may be free from the jar caused by the working of heavy machinery and the revolution of the line shaft, the latter is supported on several blocks of concrete weighing ten tons each set in the ground, and the mixing pans have similar foundations. Fourteen down-draft circular kilns are in use, some of them being of unusual size, 34 feet in internal diameter. The fuel is obtained from a coal bed overlying the clay in the company's mine at Taylor.

The total force of men employed numbers 145, of whom two-thirds are at the works, and the rest in the mines. The main products of the works are as follows:

Pressed facing brick, made in a number of different shades as above stated. Standard colors are kept on hand in large supply, and others are made to order. This brick finds a market in Seattle, Tacoma, Victoria, Vancouver, Spokane, Walla Walla, and Portland.

Vitrified or annealed paving brick, for street paving. Annealed and glazed brick is rapidly growing in favor as a street paving material,

DENNY CLAY WORKS, SEATTLE.

owing to its great strength and durability under heavy traffic, its smoothness, cheapness and the speed with which it can be laid.

REPORT OF MECHANICAL TESTS,

Made with the U. S. testing machine (capacity 800,000 pounds) at Watertown Arsenal, Mass., June 13, 1894.—Material contributed by the Denny Clay Co., at the World's Columbian Exposition, Chicago, Illinois.

DESCRIPTION.	DIMENSIONS. Height	DIMENSIONS. Compressed surface.		Sectional area	Weight dry		ABSORPTION OF WATER. Total	By weight.	By volume	First crack	ULTIMATE STRENGTH. Total	Per Sq. In.
	In.	In.	In.	sq.in.	lbs.	oz.	oz.	Per ct.	Per ct.	Lbs.	Lbs.	Lbs.
Facing brick: Denny Clay Co	2.45	8.98	4.48	40.23	6	13¾	6¼	5.6	11.00	250,000	505,800	12,573
Facing brick: Denny Clay Co	2.38	8.89	4.45	39.56	6	6¾	6	5.8	11.00	309,000	519,700	13,137
*Vitrified paving brick: Denny Clay Co	4.23	8.78	2.70	23.71	7	12¼	½	0.4	00.86	49,000	288,100	12,151
Vitrified paving brick: Denny Clay Co	2.61	8.76	4.08	35.74	7	12¼	1	0.8	1.85	55,000	761,000	21,293

* Tested on edge.

Sewer pipe, glazed, varies in diameter from 8 to 24 inches inside measurement, length two feet.

Drain tile, made in one or two-foot lengths, size from 2 to 6 inches.

Chimney pipe, tops and flues, made of high grade fire clay, in all necessary forms.

Hollow vitrified foundation blocks, in two sizes, 8½ or 12 inches in square section, and from 8 inches to 3 feet long. Being vitrified, they are impervious to moisture, while the air space in each block is a poor conductor of heat from within or cold from without.

Fire brick, in all the usual shapes, proved to possess excellent qualities as locomotive brick, furnace blocks, linings, etc. The following results are from tests made by J. W. Reilley, major ordnance department, U. S. A., Watertown Arsenal:

Area exposed to crushing	37.97 square inches
Average weight under which brick cracked	29.95 tons
Average force required to crush brick	52.49 tons
Weight when dry	5.125 pounds
Percentage of water absorbed	12

Ground fire clay. The flint clay from Kummer is mixed with a plastic clay, and by a special process of treatment is brought to a plastic condition, meanwhile retaining its refractory qualities. The mixture is dried, pulverized, and shipped in barrels, to be used as a cement in laying fire brick. From five to seven hundred pounds are required to lay one thousand brick, making the joints as thin as possible.

Sidewalk and floor tile, both plain and ornamental, partition tile of fire clay, ornamental ware, terra cotta, etc. Two small kilns are devoted to the manufacture of such ware.

Acid brick, made from very siliceous clays free from alkalies, for special use in acid and powder works.

LITTLE FALLS FIRE CLAY COMPANY.

By Milnor Roberts.

Along the Cowlitz river, a few miles above the crossing of the Northern Pacific Railway at Olequa, and two miles east of the station of Little Falls or Sopenah, an excellent exposure of clay shale occurs in the west bank of the river. At several points in its southerly course the stream has reached the western border of the bottom lands of its valley, where the strong current swinging against the bordering hills has cut away the lower banks and left escarpments several hundred yards long and thirty or forty feet high. Here may be seen sandstones interbedded with shales, both arenaceous and argillaceous, containing numerous fossils probably of Pliocene age. A portion of the shale has a finely laminated structure, but much of it is massive, in this case usually containing inclusions of very hard sandstone, fossilliferous. Although land-slips have disguised the true bedding in many places, the average dip seems to be from two to ten degrees to the northeast. Several lines of sandstone boulders stand out prominently on the face of the cliff, in beds varying from a few inches to two feet in thickness, and in these the fossil contents are much better preserved than in the adjacent shales.

Fresh specimens of shale from this locality are of a grayish drab color, commonly called "blue," while the same material, when exposed on the surface or along joint lines, turns to a light brown shade, with coatings of red oxide of iron. Small amounts of alkaline sulphates are present, showing as efflorescence, but the usually common black oxide of manganese is absent. Mica, mostly muscovite, is quite prevalent, and is especially noticeable in the fine laminated structure, where the thin plates lie parallel to the cleavage of the shale. Columnar structure is sometimes shown in the thick beds of shale, the columns being four and five sided usually (with irregular forms intervening), having a diameter of a few inches only, and not much greater length. Each column is commonly coated with a layer of thoroughly oxidized material, changing in character towards the center, which may be of original "blue."

About a quarter of a mile northwest of the above locality, on hilly ground rising from the Cowlitz river, pits have been opened up in the beds, from which several thousand yards of clay have been taken by the Little Falls Clay Works. These beds appar-

ently overlie those on the river, and their geological horizon is probably not distinct, although no connection can be traced accurately at the present time. Some difficulty is experienced in working the pits, as water accumulates in all the hollows, owing to the impervious character of the beds, and in the spring season when the whole ground is saturated, slides are frequent, bringing down the overlying gravel and debris of timber, thus covering the working face. The method of working is very simple. A level floor with a tramway is graded in the face of the hill, and the material is broken down with picks directly into cars. Nodules and boulders are thrown on the dump, along with unsuitable clay, gravel, etc. For the most part, a pick is found to be the best tool for the work on account of the easy breaking due to the joints and columns, but occasionally a large mass is loosened or thrown down with a charge of low-grade giant powder. Certain layers occur here which contain iron in such quantities as to give them a rather brilliant orange-red appearance. Some of the layers of the blue are practically unweathered and have the same appearance throughout.

Pits have been opened at other localities in this region, yielding clays of economic value. Especially good clay, both blue and white, has been obtained in the valley of the Cowlitz river, about four miles above the place described.

In the year 1891, the Washington Fire Clay Company began the manufacture of brick and pottery at Sopenah, a station on the Northern Pacific Railway, midway between Tacoma and Portland. During the years 1894–5 the works lay idle, but since that time have been running quite steadily, for the past three years under the name of the Little Falls Fire Clay Company.

A tramway nearly two miles long leads from the works to the pits described above. Owing to the grades on the line, a car carrying one and one-half tons is found to be a full load for a horse to pull. Clay has also been brought by wagon from pits further up the Cowlitz river and other points near at hand, as well as from Gale creek.

The company's works are very compact, all the manufacturing and drying being done under a single roof, while the kilns are placed under an adjoining shed. The main building is of brick, three stories high, and has an inside measurement of 80 by 250 feet, giving a total floor surface of 60,000 square feet.

As the main purpose of such a large building is to give drying room, the builders kept that idea in mind throughout its construction. The flooring is of 1¼-inch stuff, set three-eighths of an inch apart, thus allowing free circulation of air from basement to roof. The heating plant, located in the basement and ground floor at the center of the west side, consists of two return tubular boilers (66 inches by 16 feet, with 56 flues apiece), connected at the bottom by a mud drum and at the top by a steam dome 28 inches by 12 feet. Two supply pipes, 1¼-inch diameter, carry live steam to two 8-inch headers, placed one in each end of the building, from which radiator pipes extend the whole length of the building, 250 feet, at intervals of six inches or less, making a total length of over seven miles of pipe. This great radiating surface serves to keep a volume of warm air circulating through the whole building aided by the spaced flooring. The drip of the dead steam returns by gravity to the boiler room and is pumped while hot into the boilers.

A 6-inch pipe supplies steam to the engine, a Nordberg Corliss, 16 by 36 inches. The main line shaft runs part way across the center of the building on the first floor. The brick presses are also on the first floor. The remainder is used as a drying floor, where the brick and tile receive their final drying before going to the kilns. Drain tile, sewer pipe and flue lining are made in a press on the second floor; the steam cylinder which furnishes the compressing power is set between floors, and the tempered clay is fed into the press on the third floor, where the screening machinery is placed. The company's office occupies the southeast corner of the second floor. On account of the fact that the drying of the pressed material must be done slowly and carefully at first, to avoid cracking, it is customary to send the products of the presses up to the third floor, farthest removed from the steam pipes, where, after two days' drying, the necessary trimming is performed.

The clay brought from the pits in tram cars, is dumped in heaps under sheds, each class by itself. It is then wheeled to the grinding pan and after being crushed is elevated to the third floor, screened through a trommel, and sent down to the mixing or wet pans.

Clay that has been mixed, screened and tempered to a proper degree of plasticity for pipe making, is elevated to the third floor

and there fed to the steam press. A 4-inch pipe supplies steam at a 95 pounds pressure to a cylinder 44 by 36 inches. Under this enormous pressure the moist clay is easily forced down through the mould. For making sewer pipe a "former" is set at the bottom of the mould to form the joint head or shoulder of the pipe. Steam is let into the cylinder until the triple piston rods are forced down a few inches, filling the "former" with with clay. Next, the "former" is lowered and swung aside, steam is again admitted and enough clay is squeezed down through the mould to give a length of 29 or 30 inches to the pipe. Steam is shut off, the pipe is cut by a jack-knife folding up inside the mould, and the pipe is placed on a truck and hauled to the drying floor. The "former" is greased and swung back into position ready for another length. Four men are required to handle the pipe press, one to regulate the steam in the cylinder, one to handle the "former," and two to cut and lift off the finished pipe.

In making drain tile, or any straight pipe without a shoulder, great speed may be attained. As many as 2,500 pieces of tile of four inches inside diameter can be turned out on a single press in one day. One thousand five hundred would be a good day's run of 3-inch pipe, 1,000 for 8-inch, while in making the heavy 2-foot sewer pipe 200 pieces is about the working limit for ten hours' time. All these sizes are made on the same press, by changing the mould. After drying for two days, the pipe goes to the hands of the finisher, who cuts and fits the elbows, and trims to proper length, allowing for a shrinkage of one inch in eight, so that the burned pipe shall be two feet long. Ten days or two weeks is required for the final drying.

Paving brick which is to undergo vitrification is formed in a somewhat similar manner. A horizontal steam press forces a steady stream of clay through two moulds side by side, with opening 2½ by 4½ inches. As the stream of moulded clay issues it is cut into 9-inch lengths by means of a revolving wheel carrying pieces of fine steel wire stretched taut. An endless belt conveys the bricks to another machine where they are pressed again. Dry pressed brick is made by running rather dry clay into separate moulds, which are subjected to a high steam pressure. Special tempering is required, in order that the brick

shall be stiff enough to hold a sharp edge, but will not crack on drying after being greatly compressed.

Six kilns are in use at the Little Falls works, all of them circular, 30 feet in diameter, 12 feet to the crown inside, with 10 or 12 fireplaces apiece. Down-draft is obtained by means of "bags," which direct the heat from each fire against the crown; the floor is built of spaced brick, through which the air is drawn to underground flues leading to stacks 65 feet high, one for each pair of kilns. Sewer pipe is stacked in the kilns on end, three rows high, and burned for about six days. "Try-pieces" of clay are placed inside near the door, where they can be removed by taking out a plug in the door. The kiln man in charge of the burning is thus able to tell its rate of progress. At the finishing point of the burning, vitrification is caused by scattering one or two shovelfuls of salt over each fire, using about 200 pounds to a kiln. Three or four hours later the process is completed and the kiln may be opened gradually, cooling throughout in three days. Pipe that has entered the kiln in a "green" state, that is, not thoroughly dry, usually shows white streaks and blotches on its surface, and fails to vitrify.

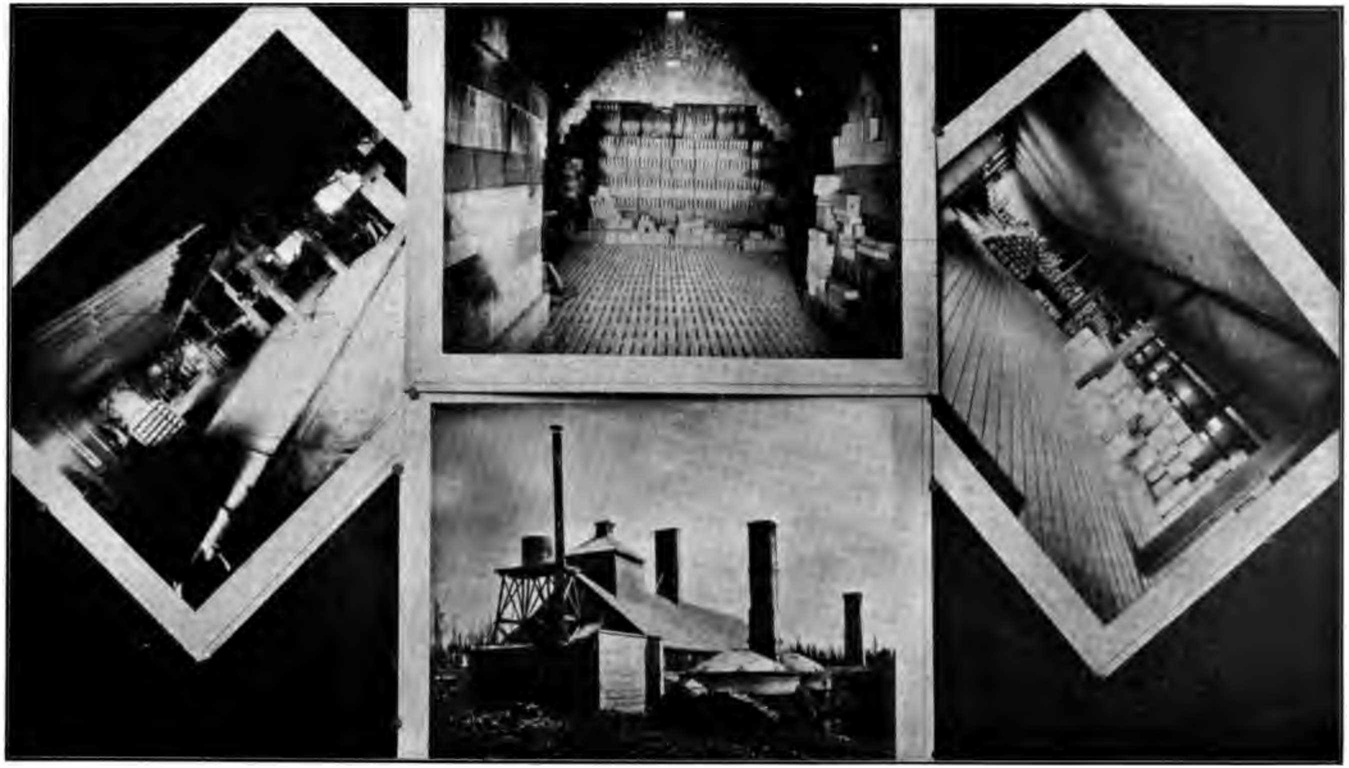
Dry pressed brick is heated slowly and burned carefully for ten or twelve days, the time varying with the character of the clay and the amount of heat it requires. Both pipe and brick attain a white heat, from which the brick will not cool in less than four days, on account of absoption due to thickness. Sections of pipe are nested, the small within the large, giving a kiln capacity of more than one thousand pieces.

The following figures showing the output of the Little Falls Fire Clay Company for the year 1901 were furnished by the manager, Mr. R. P. Bradley:

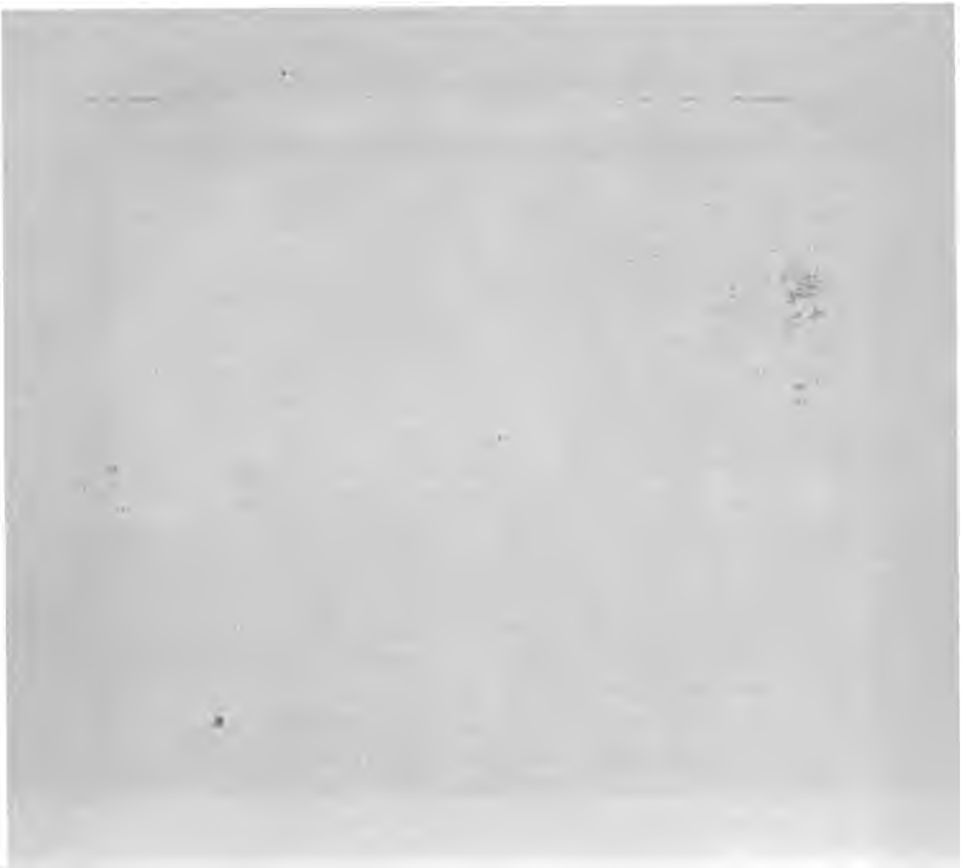
Total feet of sewer pipe, all sizes	136,196
Branches, 2-foot lengths, all sizes	8,876
Curves and elbows, all sizes	1,863
Other sewer pipe fittings, pieces	127
Feet of drain tile, 3-in. to 8-in	24,488
Paving brick	106,400
Face brick, dry press	228,500
Fire brick	10,500

WASHINGTON BRICK, LIME AND MANUFACTURING COMPANY.

Beside the plants engaged in the manufacture of common brick for the Spokane market there are several companies turn-



PLANT OF THE WASHINGTON BRICK, LIME AND MANUFACTURING COMPANY AT CLAYTON.



ing out high grade clay products whose market is not by any means confined to that immediate vicinity. The most important of these is the Washington Brick, Lime and Manufacturing Company with headquarters at Spokane and works at Springdale and Clayton, Stevens county, and at Freeman, Spokane county. The plant at Springdale is engaged in the manufacture of lime and has been described under that heading. The Clayton works, situated on the line of the Spokane Falls & Northern Railway about twenty-five miles north of Spokane, is the most important of the company's plants. There is here a fully equipped clay manufacturing plant employing seventy men, engaged in the production of common and pressed brick, architectural terra cotta, fire proofing and drain tile. The market for their product includes all the larger towns and cities of Montana, Idaho, Washington, British Columbia and Oregon. Numerous recent orders from Seattle, Boise and elsewhere have kept them running at full time. Fire proofiing and terra cotta for the new Great Northern depot at Spokane and the Masonic temple at Butte are among the most recent orders filled.

The Freeman plant, on the O. R. & N. Railway about fifteen miles southeast of Spokane, manufactures common and fire brick of superior quality. There are about forty men employed about the works. (H. Brooke.)

LIMESTONE.

INTRODUCTION.

Limestone suitable for lime-burning has been discovered at many places in Washington. It is found in a crystalline condition among the ancient rocks of the Okanogan highlands and the northern Cascades; and well-known deposits of it occur on both San Juan and Orcas islands. Wherever it is found it is wholly or partly converted into marble, and always gives evidence of much metamorphism. As a rule the limestone is a very pure calcium carbonate, although magnesium carbonate is sometimes present.

Lime belongs to that class of heavier building materials which can not stand the expense of long transportation, especially the usually heavy expense of land transportation. Lime weighs so much in proportion to its value that freight charges soon increase the price until the latter becomes prohibitive. For this reason we find a number of small kilns scattered about the state supplying the local markets, especially in the interior. Some of our lime kilns, however, are so conveniently situated in regard to cheap water transportation that they are able to supply a much more extended market and are consequently able to conduct operations on a very large scale. The lime-burning industry is more than keeping pace with the industrial development of the state along other lines. Not only are we able to supply all local demands, but we are also able to make heavy shipments to points outside the state.

SAN JUAN ISLANDS.

The San Juan islands are the center of the lime burning industry of western Washington. The principal plant on the islands, the Roche Harbor lime works, is the biggest concern of its kind in the state, if not on the Pacific coast. It manufactures more lime than all the other kilns in the state combined. Its output at the present time is about fifteen hundred barrels per day. The plant is thoroughly modern in every respect, and is under the very efficient management of Mr. John S. McMillin, the president of the company. The company has the largest

deposit of pure limestone thus far discovered on the islands. It extends all the way across the peninsula from Roche Harbor to Westcott bay, a distance of half a mile. The width of the outcrop is about eight hundred and fifty feet, and the average thickness above water level two hundred and fifty feet. It extends below water level to an unknown depth. The quarry is worked from a steep face close to the water's edge and at a sufficient elevation to employ the gravity system. From the time the stone leaves its original position in the quarry until it reaches the steamer its course is always down hill. In the quarry air drills are employed in putting in the holes and giant powder is used in blasting. In work of this character the aim is of course to break as much rock as possible with each shot irrespective of its fineness or coarseness. The stone as it is blasted loose rolls to the bottom of the slope where the larger pieces are broken with a hammer; the finely broken stone is next loaded onto iron dump cars which are then run down an incline track to the chutes above the kilns. The stone is then dumped into chutes each one of which communicates with the upper opening to a kiln. The stone is fed into the kiln from above as fast as the burned lime is drawn off from the bottom. The fires are never allowed to go out except when it becomes necessary to reline the furnaces, which does not occur very often. Each kiln holds thirty tons of rock.

The length of time required to turn limestone into lime depends on the intensity of heat generated in the furnace. The kilns are of the Monitor pattern, consisting of two inner layers of fire brick, an outer layer of ordinary red brick and a sheeting or jacket of boiler iron riveted together. Between the outer layer of brick and the jacket there is a space of about two inches filled with ashes and small pebbles to act as a non-conductor of heat and also to relieve the iron jacket from the strain caused by the expansion of the bricks due to the intense heating of the interior. Each kiln is fired by two furnaces, one on each side, and consumes about a cord and a half of wood each day. Each kiln is surmounted by a smokestack of boiler iron. These increase the draft and so cause a more nearly perfect combustion of the fuel. By increasing the intensity of the heat the smokestacks reduce the time necessary to burn the lime and thus add to the capacity of the plant. Underneath the firebox there is a

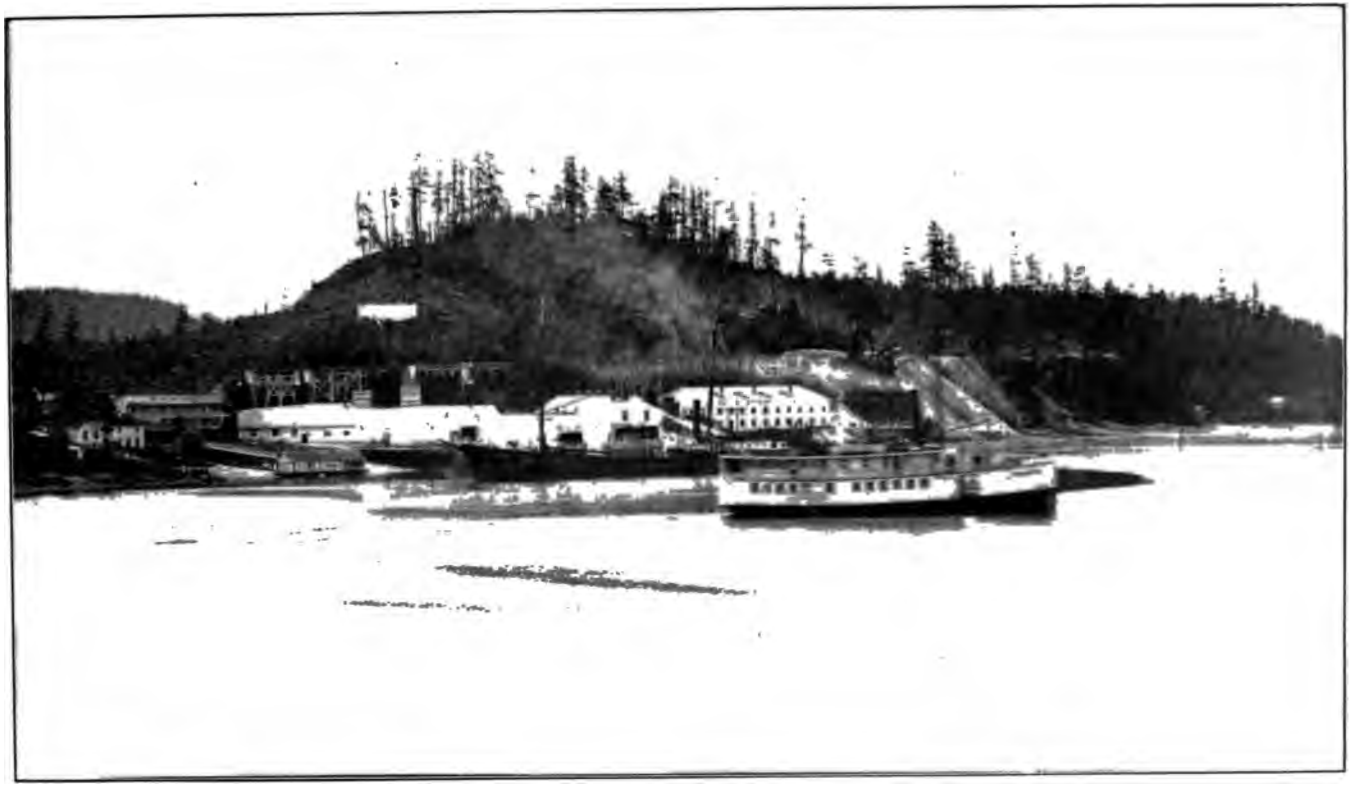
cooling receptacle into which the lime falls after it has become thoroughly burned. There is a system of cold air drafts in the cooler which carries off all the dust and gases and greatly hastens the process of cooling. From the cooler the lime is drawn through a chute directly into barrels of a capacity of two hundred pounds each. The barrel stands on a platform scale as it is being filled and when exactly two hundred pounds have been drawn the barrel is passed along and another empty one takes its place. The heads are put in the barrels by workmen skilled in the business, and from them the barrels are hauled in large trucks to the warehouse on the docks. The company always keeps a reserve stock of several thousand barrels in its warehouse with which to fill emergency orders on short notice. There is a good deep water harbor so that vessels of the largest size may come alongside of the wharf and load. The plant could not be more favorably located as far as cheap water transportation is concerned. The abundance and purity of the raw material, the unsurpassed transportation facilities, and the very efficient management are the three factors which have combined to build up this great industry. The following analysis of the limestone shows in a striking manner its exceptional purity:

	Per cent.
Silica	.25
Iron and alumina	.80
Phosphorus	.10
Carbonate of lime	98.85
	100.00

The company owns and operates its own barrel factory on the premises. Fir is the only wood employed in making the barrels and it has been found to be admirably suited for that purpose.

Besides using the limestone for the manufacture of lime the company has been shipping large quantities of the raw material to different smelters to be used as a flux in their blast furnaces. The stone for this purpose is run out of the quarry on cars and dumped into a long chute which leads directly to the scows onto which the limestone is loaded. The scows are then towed by means of tug boats to their destination.

Besides the plant at Roche Harbor there are a number of smaller plants burning lime in different parts of the San Juan group of islands. The chief drawback thus far encountered by most of them is that they cannot find large bodies of good limestone. The stone occurs only in isolated fragments embedded



ROCHE HARBOR LIME WORKS.

usually in an eruptive rock. These fragments are usually of small size, the largest thus far found being that owned by the Roche Harbor Company.

Henry Cowell & Company have a plant of two kilns located on the west coast of San Juan island, and about seven and one-half miles from Friday Harbor. The plant has a capacity of two hundred and thirty barrels per day. The kilns are built of sandstone and limestone, and lined with a double row of fire bricks. A gravity track runs from the quarry to the kilns, and from the kilns to the wharf. Most of the lime is shipped to the cities and towns of Puget Sound, and to Portland, Oregon. Occasional shipments are made to San Francisco and Hawaii.

At several places on Orcas island, notably near East Sound and Deer Harbor, small deposits of limestone occur. Along the water's edge near these lime outcrops several kilns have been built and in them considerable lime has been burned. The unexpected exhaustion of the supply of stone has caused some of the kilns to become idle. At the present time lime is being burned near Deer Harbor by two companies, one, the Eagle Lime Company, operating one kiln of 120 barrels capacity, and the other, the Island Lime Company, operating a kiln of 80 barrels capacity.

GRANITE FALLS.

Three miles east of Granite Falls, on the Everett & Monte Cristo Railway, is the quarry of the Canyon Lime and Cement Company. The property embraces a little more than twenty acres, or one full mining claim. The quarry is located alongside the railway and the stone is loaded directly onto the cars on the company's sidetrack. The quarry has been in operation for a year and a half, and from it at the present time there is being shipped about sixty tons of limestone per day. Regular shipments have been made to the Everett smelter ever since the quarry was opened. Shipments are also made to Seattle and other places. There is a first-class modern lime-kiln installed, having a capacity of one hundred barrels per day. From three to five hundred barrels of lime have already been made and shipped. An analysis of the lime gives the following constituents with the percentage of each:

	Per cent.
Silica	0.60
Iron oxide	1.15
Calcium carbonate	98.43
Magnesium	0.80

SPRINGDALE.

The Valley-Brook White Lime Works, located at Springdale, Stevens county, belongs to the Washington Brick, Lime and Manufacturing Company of Spokane. The property consists of about 640 acres of land, and the necessary equipment and machinery for the daily production of 500 barrels of lime, which is the present output. The Spokane Falls & Northern Railway passes through the property, and the sidings, switches, etc., provide cheap facilities for the loading and transportation of the lime.

Wherever the solid rock formation outcrops on the company's land it is limestone. Pits dug at different points, and cuts made where the formation does not outcrop, all show that limestone is the country rock throughout the entire tract. Analyses have been made from various outcrops of limestone with the following general results:

Calcium carbonate	96 per cent. or more.
Magnesium carbonate	3 per cent. or less.
Silica	1 per cent. or less.
Total	100 per cent.

Analyses made from one special quarry, with a view of supplying the paper mills with a high grade magnesian limestone, showed the contents given below:

Magnesium carbonate	47 per cent. and under.
Calcium carbonate	52 per cent. and over.
Silica, a trace to	1 per cent.

Shipments of the magnesian limestone were made to the Willamette paper mills, and the rock was found to be well suited to their purpose, but the freight rates would not permit of extended shipments at a profit, and so they were discontinued.

The equipment consists of four continuous kilns, capacity 500 barrels daily, track, cars, and other necessary machinery; buildings, consisting of store houses, office, residences, etc.

There is a constant and growing demand for the lime produced, but the rock carrying the high percentage of magnesium carbonate will not be in demand until paper mills or other manufactories are located sufficiently near so that freight rates will not interfere with its use, or the rates to those mills now using it are reduced.

REPUBLIC.

There is a small lime kiln between Republic and Wauconda that has produced a considerable quantity of lime for local use.

QUARRY OF THE VALLEY-BROOK LIME WORKS, SPRINGDALE.

LIME KILNS, VALLEY-BROOK LIME WORKS, SPRINGDALE.

The stone found here is a bluish, compact limestone, checked with light blue granular marble with very little spar of any sort. An analysis made by S. G. Dewsnap gave the following result:

	Per cent.
Calcium carbonate	98.2
Silica	.6
Magnesia	trace
Phosphorus	trace
Sulphur	trace
Organic matter and water	1.2
	100.00

SOILS.

GENERAL STATEMENT.

ORIGIN OF SOILS.

The rocks which form the crust of the earth are everywhere at their surface exposed to the disintegrating action of air and water. Soil is simply the decomposition product, the insoluble residue left after nearly all the soluble portion has been carried away by percolating waters. It is evident therefore that the elements which constitute the soil must have existed in some form or other in the parent rock. It does not follow, however, that the resultant soil resembles in chemical composition the rock from which it was derived, in fact analyses usually show them to be widely dissimilar. This is conspicuously the case in limestone regions where the lime in many cases has been almost entirely leached out of the soil, although forming the great bulk of the underlying rocks. In these cases the greater part of the soil is made up of constituents which formed a very small portion of the parent rock, and we must bear in mind that one foot of soil usually represents the residue left by the decomposition of a great many feet of the solid rock.

Rocks lying at any considerable distance below the surface of the earth are protected from the destructive agencies of the atmosphere, and undergo little or no alteration from these causes, but when in the course of time the rocks above them are denuded and carried away by the streams to be re-deposited somewhere else, then these underlying rocks are exposed in their turn. The agents of disintegration which exist in the atmosphere and in the soil act usually from the surface downward, so that it is always the surface of the rock which is being most attacked and any cause which increases the surface area accelerates the work of destruction. Thus the mechanical agents of air and frost which are at work breaking up the rocks act as pioneers for the chemical forces which follow them. Usually, however, most or all of these forces are working together at the same time. The agents which are at work disintegrating the rocks may be divided into

two classes: 1st. Mechanical, 2nd. Chemical. Each of these may be subdivided into the forces of air, and water.

DISINTEGRATION OF ROCKS BY MECHANICAL AGENTS.

AIR.—The corrosive action of wind-blown sand in certain localities in the Middle West has carved the rocks into many fantastic shapes. This corrosive action is of course greatest nearest the ground, since most of the sand carried along by the wind is not raised far above the surface. The result is that the bases of the cliffs are continually being carved out until they become top-heavy and topple over. In comparatively arid regions like certain parts of eastern Washington where the prevailing winds are from the west or southwest, the result is shown in the form of the hills, the side exposed to the wind having its fine material carried away as fast as formed and re-deposited in more protected places. The etching effect of wind-blown sand is on the same principle as the mechanical device known as the sand blast, used in certain industries.

The rocks which form the great mass of the earth's crust are made up of a number of minerals, each having a different coefficient of expansion, so that under a change of temperature the minerals expand or contract in different degrees, thus setting up internal strains which tend to force the particles apart. The same disintegrating effect may take place in rocks of uniform texture and composition due to the unequal heating and cooling of different parts of the same rock.

WATER.—The mechanical effect of water from the soil-forming point of view is nearly all of the destructive sort. The ultimate fate of all soil is to be carried away and deposited in the sea. The material which forms the crust of the earth is continually going through a great cycle of change. It passes from solid rock to soil, is carried by the sreams down to the sea, is there deposited as sediment on the sea floor and during the succeeding ages is covered up by sediments to a depth of perhaps many thousands of feet. When these sediments have been hardened into rock, through causes little understood, they are usually elevated until they become parts of the land, and the work of erosion and deposition begins anew. We are only concerned here, however, in that stage when the rock has crumbled into soil and has not yet been carried away to the sea.

The journey of the soil from the place of origin to the sea is usually one of many stages. The soil of steep hillsides is carried away almost as fast as formed and deposited in the stream bottoms, where it accumulates often to considerable depths. Thus we have transported soil in distinction to soil that is formed in situ.

Frost is the most powerful natural agent in the mechanical disintegration of rocks. Water in passing from the liquid to the solid state undergoes a sudden increase in volume so that 100 parts of water are changed into 109 parts of ice. All rocks in their natural state are more or less saturated with moisture. When this freezes, an expansive force equal to 150 tons to the square foot is exerted tending to force the rock apart.* Any crevices which are filled with water are forced further apart when the water freezes so that the whole mass of the rock is gradually torn asunder. This force is most active on cliffs and steep hill sides where the blocks fall downward as they are riven off. Good examples of this may be seen in the talus slopes at the bottom of the basaltic cliffs bordering the stream valleys of southeastern Washington. There the frost, combined with unequal heating and cooling, has gradually wedged off and broken up the basalt into angular blocks usually of a fairly uniform size. In this particular case the cleaving action of frost seems to have stopped at a certain point, beyond which further weathering is due to chemical forces which cause the blocks to crumble into fine dirt.

DISINTERGATION OF ROCKS BY CHEMICAL AGENTS.

AIR.—There is no clear line of distinction between the chemical changes effected by water and those effected by air. The chief constituents of air by weight are nitrogen 75.66 per cent., oxygen 23 per cent. and varying small proportions of carbon dioxide and water vapor. The nitrogen is entirely inert. When the air is very dry neither the oxygen nor carbon dioxide exercise any chemical effect upon the rocks, but when moisture is present in the air they become active agents of disintegration. Among the minerals the feldspars are attacked by the carbon dioxide, and their soda, potash, and lime constituents are carried away in solution, leaving a residue of kaolin. Such minerals as pyroxene, amphibole, and mica have their iron constituents oxidized and carried off in solution.

* Geo. P. Merrill: Rocks, Rock Weathering and Soils, p. 198, New York, 1897.

A striking example of how different climates affect rocks is shown in the rapid decay of the Egyptian obelisks brought to Europe and America. During the few years since their removal in which they have been exposed to the damp, changeable climate of temperate latitudes, they have decayed more than during all the centuries in which they stood in Egypt. The dry, equable climate of Egypt affected them hardly at all.

WATER.—Absolutely pure water has very little, if any, solvent action upon the minerals composing the rocks, but pure water does not exist in nature. Meteoric waters in their passage from the clouds to the earth and into the soil take into solution a number of acids and other impurities both organic and inorganic. Water in this condition is almost a universal solvent. Its action upon the rocks from day to day is of course imperceptible, but the total effect lasting through years and centuries is very great. The chief acids in water which act as solvents are carbonic acid, humic, ulmic, and other organic acids which the water takes up in its passage through the soil. One of the principal effects of water upon the rocks is seen in the oxidation of the iron constituents of the silicates and their removal by solution, leaving the rest of the rock to crumble into dust. The most insoluble constituent of the rock-forming minerals is silica or quartz, so that it forms by far the largest proportion of the residue after the soluble portions of the rock are carried away. The higher the temperature the more active are the chemical forces and the more rapid is the disintegration of the rocks.

FERTILITY OF SOILS.

The fertility of soils is dependent upon: 1st, Chemical composition; 2d, Physical condition; 3d, Climate.

CHEMICAL COMPOSITION.

A soil in order to be fertile must contain all the elements necessary for plant nutrition in adequate proportions and in soluble form. Silica forms the great bulk of all soils. In lesser amounts are alumina, iron, magnesia, lime, potash, soda, phosphoric acid, sulphuric acid and nitric acid. The three ingredients which are essential to plant growth and which are most likely to have to be renewed are lime, potash, and phosphoric acid. Potash in the form of feldspar and phosphoric acid in the

form of apatite are not available for plant nutrition because they are in an insoluble form. Where there is a large amount of lime present smaller proportions of potash and phosphoric acid are sufficient than where the lime is in lesser quantities, so that in many soils which contain potash and phosphoric acid in small quantities all that is necessary to insure permanent fertility is to add lime to the soil, usually in the form of calcium sulphate or gypsum. Nitric acid in some form is essential to plant growth. The process of nitrification changes the inert nitrogen of the air into a form whereby the plant can assimilate it.

All soil contains humus or vegetal mould in a greater or less proportion. Besides its chemical effect, it performs an important function in keeping the soil loose and porous, and thus facilitates the passage of moisture.

PHYSICAL CONDITION.

It sometimes happens that a soil rich in all the elements of fertility and blessed with a salubrious climate still obstinately refuses to yield good crops. This is due to some defect in its physical condition whereby it is unable to receive and retain the requisite heat and moisture. If the particles composing a soil are too coarse the water passes quickly through it, so that in dry weather vegetation perishes for lack of moisture. This is conspicuously the case on some of the gravel plains lying to the southward of Tacoma and Olympia. On the other hand, if the particles composing a soil are too fine it becomes caked and impervious to moisture. In this condition it is hard to cultivate and crops usually do not thrive.

CLIMATE.

In a general way it may be said that the warmer the climate the more luxuriant the vegetation, providing the moisture is adequate. Some plants require a hot growing season, but are able to stand a severe winter, while others require a more equable temperature throughout the year, so that there is no very rigid standard of comparison. Probably nowhere on the American continent is there a more striking instance of the effect of climate upon vegetation than in the state of Washington. On the western side of the Cascades the climate is very moist and there are no great extremes of heat or cold. The result is that we have here the densest vegetation of any place on

the continent. East of the Cascades there are far greater extremes of temperature and the rainfall is very slight, especially in the central part of the state. The scanty vegetation is all of the desert type—sage brush, cactus and greasewood. The difference in vegetation between these two parts of the state is due mostly to the difference in the amount of rainfall, and to a much lesser extent to the greater variations of temperature in eastern Washington.

For every average temperature there is doubtless a maximum rainfall beyond which any more rain would not increase the vegetation. It is probable that this point of saturation has been reached in parts of western Washington, but it is by no means a common occurrence in tropical and temperate climates and there are probably very few places outside of the high latitudes where an increase in rainfall would not be followed by a greater luxuriance of natural vegetation.

The direct effect of winds upon vegetation is not great. Winds, however, affect temperature and rainfall most vitally. Using again as an example the difference in climate between eastern and western Washington, we find that the equable climate of western Washington is due to the warm, moist, prevailing westerly or southwesterly winds which blow off the Pacific ocean. It is well known that a large body of water is not subject to such extremes of temperature as a large body of land, so that the winds which blow off the ocean are warmer in winter and cooler in summer than those which blow off the land. The moisture laden breezes of the Pacific pass over western Washington and up the slopes of the Cascades and down into eastern Washington. By the time the Cascades are passed much of the moisture has been precipitated as rain or snow, and the air has been greatly cooled by passing over the high altitudes. It is therefore dryer and cooler.

WASHINGTON SOILS.

SOILS OF WESTERN WASHINGTON.

The soils of Washington are the result of geological conditions widely dissimilar in the different sections of the state. All of western Washington, except the southwestern part, is a region that in comparatively recent geological times, has been covered deep with glacial ice. The glaciers which filled the

greater valleys of Puget sound during the geological period, came from three directions. First, there were the glaciers moving eastward from the Olympic mountains; second, the glaciers moving westward from the Cascades; and third, the great southward moving body of ice which came from the mountains of British Columbia, and greatly exceeded in volume the other two combined. The heterogenous mass of earth and rocks carried along by these ice streams was deposited upon the melting of the ice, and now forms the great mantle of drift which nearly everywhere covers the bed rock of the Puget sound basin. The soil formed by the weathering of this glacial material is usually quite fertile. The soil of the uplands in its virgin state supports an exceedingly heavy forest vegetation, and when this is cleared away very good farm lands are thereby produced. The bottom lands when not too swampy are exceedingly fertile, and grow in profusion all kinds of crops suitable to a temperate climate. These soils, owing to the heavy vegetation which they have supported in their unreclaimed state, are very rich in humus or vegetal mould. Here and there throughout the glaciated region there are are found lake beds, where old lakes have become entirely silted or filled up. These always have a very fertile soil, and yield excellent farms when well drained. A lake such as described once occupied the Snoqualmie valley above the falls, including the country about the present towns of North Bend and Snoqualmie.

The larger streams flowing into Puget sound have flood plains in their lower courses which contain some of the richest agricultural lands in the state. The Skagit flats and the White river valley belong in this category. The soil is a very fine silt brought down from the upper reaches of the river and deposited a thin layer at a time, during seasons of extreme high water. Like the ancient valley of the Nile the fertility of the soil is annually renewed. The silt which fills the valley of the White river has been brought down from the muddy streams flowing from the glaciers of Mt. Rainier, and like the product of all volcanic rocks, is extremely rich in the essential elements of fertility.

The giant glaciers that were mentioned above did not extend as far south as the Columbia river, so that in southwestern Washington there is a large area where the soils of the highlands are composed of the residue left by the decomposition of the

rocks immediately underlying them. The rocks here are mostly sandstones and shales of the Tertiary period, capped in places by basalt. The valley soils have been washed down from the highlands and are probably nearly the same in composition but finer in texture and richer in vegetal mould.

The glacial drift of western Washington does not usually extend up the flanks of the Olympic and Cascade mountains above an altitude of two thousand feet. Above this the soils are mostly residual and comparatively thin and probably will never be of any great value for agricultural purposes.

SOILS OF EASTERN WASHINGTON.

By reference to the geological map accompanying this report it will be seen that one of the chief geological features of eastern Washington is the vast lava plain extending from the foot hills of the Cascade mountains to the eastern boundary of the state and from the Columbia and Spokane rivers on the north southward to Oregon. The rock is a basalt, very rich in minerals containing iron, lime, potash, and phosphoric acid. Everywhere in this area where the rock has decomposed sufficiently to form a soil, and the rainfall is at all adequate or water can be procured by irrigation, the land is very fertile and is rapidly being brought under cultivation. The soil of the highlands has been formed in situ and the solid rock is usually not far below the surface. Owing to the fact that the rocks below act as a reservoir for moisture and yield it up gradually during the dry months of summer a very little rainfall is sufficient.

Succeeding the period of the lava outflows there came a time in its geological history when large lakes were formed within the region now under discussion. These were finally drained, and most of the sediment which had been deposited in them has been carried away by the streams, but in some localities large areas still remain. The soil formed by the weathering of these sediments is usually of a sandy nature. It occurs in patches all along the course of the Yakima river, also in the western part of Franklin county and the southern end of Douglas county. This region is one of scanty rainfall, so that it has been found necessary to resort to irrigation in order to raise crops. Wherever this has been done the dry and barren sage-brush desert has been converted into a garden and made to support a large and thriving population.

The only cloud on the horizon which threatens the prosperity of the irrigated districts of the lava plain is the continual spreading of the alkali area. In regions of abundant rainfall the soluble salts formed from the decomposition of the parent rock are carried away in solution almost as fast as formed, but where the rainfall is scanty the water does not flow off in underground channels but rises to the surface and evaporates during the succeeding dry weather. Thus the salts instead of being carried away accumulate in the soil. They are carried upward by the ascending moisture during dry weather and upon evaporation of the moisture they form a crust or scum upon the surface of the ground. Farmers usually recognize two kinds, black alkali and white alkali. Black alkali is more injurious than white alkali. It is composed mostly of carbonate of soda, and has the power of dissolving the humus of the soil. Upon evaporation the dissolved humus leaves a dark ring about the deposit, which gives it its distinctive name. White alkali is mostly sodium sulphate and is not quite so harmful to vegetation. In the irrigated regions along the Yakima river, especially in the Kittitas and Yakima valleys, what to do with the alkali has become a serious problem to the farmer. It is only when the land has been under cultivation for a number of seasons and where it receives the drainage from land lying higher that the effects of the alkali are seriously felt. In bulletin 49 of the Experiment Station of the Washington Agricultural College and School of Science, Professor W. H. Heileman takes up the subject at length and suggests a number of remedies.

Towards the end of the Glacial period the Columbia river, together with the other streams in the northern part of the state, was charged with more sediment than it could readily carry, with the result that instead of cutting its valley deeper it kept filling it up, until the old valley was filled many hundreds of feet deep with gravel. After the ice had all gone and normal conditions again prevailed, the river carried off to the sea most of this sediment, but has left remnants all along its upper reaches in the form of gravel terraces, at various elevations above the river. Where water can be had for irrigation from the lateral streams flowing into the Columbia, these level topped terraces are cultivated. Owing to the light condition of the soil, the dryness of the climate, and the high winds which prevail,

the soil is largely windblown. It is exceedingly rich and some of the finest fruit farms in the state are in this section.

Along the lower course of the Wenatche river the rocks are sandstones of Eocene age. They form, on decomposition, a light soil largely of fine sand which is easily carried about by the winds. This, mixed with glacial material brought down by the river, has formed a very fertile soil. Whenever water can be obtained for irrigation the soil yields abundantly, and up to the present time no trouble has been experienced from alkali. The general appearance of a soil gives little indication of its fertility. One can hardly conceive of any soil more barren and desolate than that which is found in many places along the Columbia river. It consists almost wholly of drifting sand, in the summer time dry as powder, and needing only the slightest puff of wind to send it whirling, yet when water is turned upon it crops grow as if by magic.

North of the Columbia lava plain, between the Columbia and Spokane rivers on the south and the international boundary line on the north there is a wide belt known in a general way as the Okanogan country. The hills are made up of granites, schists, gneisses and other crystalline rocks of ancient origin. The soil, as might be expected, differs very materially from that to the southward. These ancient rocks are composed very largely of complex silicates, such as feldspar, amphibole, pyroxene and mica. These are comparatively rich in the elements of fertility, so that we usually expect to find soil quite fertile when it is derived from such rocks. Because of the small amount of rainfall, however, nearly all of the farming that is done in this part of the state at the present time is on the terraces of the rivers where little lateral streams come in in such a manner as to afford water for irrigation. The rest of the land is given up to stockraising.

All along the eastern slope of the Cascade mountains there is a wide belt given over chiefly to pasturage. The soil is mostly formed by the disintegration of the rocks immediately below and is of at least ordinary richness, but above an altitude of about two thousand feet farming cannot be carried on successfully. Owing to the limited rainfall the timber is not heavy, and in the open glades of the forest the pasture is excellent. Large bands of cattle, sheep and horses belonging to the farmers of the lowlands are pastured here every summer.

The following analyses of Washington soils, made by Professor Elton Fulmer and Mr. C. C. Fletcher, are taken from Bulletin 13 of the department of chemistry, Washington Agricultural College and School of Science.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Insoluble residue	76.494	78.7114	78.434	75.855	28.352	69.653
Insoluble silica	62.831	65.768	60.207	66.668	21.649	69.653
Combined silica	13.663	12.943	18.227	9.187	6.703	
Soluble silica	.301	.016	.210	.033	.181	.022
Potash (K_2O)	.635	.331	.433	.008	.137	.448
Soda (Na_2O)	.374	.568	.374	.286	.191	.504
Lime (CaO)	1.081	1.512	1.213	.769	.379	.781
Magnesia (MgO)	.727	1.527	.788	.426	.036	.123
Peroxide of iron	4.554	4.610	5.158	3.587	1.055	4.823
Alumina (Al_2O_3)	7.526	5.930	6.891	6.465	4.301	8.137
Phosphoric acid (P_2O_5)	.142	.182	.101	.054	.313	.345
Sulphuric acid (SO_3)	trace	trace	trace	.038	.093	.049
Chlorine	.020	.015	.006	.007	.018	.006
Water at 120 degs. C.	4.523	2.731	3.453	3.120	11.760	3.498
Volatile and organic matter	3.612	3.745	3.019	9.160	52.874	11.618
Totals	99.992	99.881	100.79	99.808	99.691	100.00
Humus	.995	.610	.255	2.001	6.915	3.465
Nitrogen	.110	.141	.087	.234	1.347	.720

No. 1.—Typical soil of the Palouse country, taken from the college farm, Washington Agricultural College and School of Science, Pullman, Whitman county.

No. 2.—Farm of J. B. Holt, Wawaiwai, Whitman county, located on the bank of Snake river. Soil is mostly sand.

No. 3.—Sage brush soil from S. W. ¼ sec. 12 T. 14 N. R. 18 E. near North Yakima.

No. 4.—Glacial soil from Anacortes, Skagit county.

No. 5.—Typical marsh soil of western Washington from near Anacortes, Skagit county.

No. 6.—Granite soil from garden of A. L. Smith, twelve miles northeast of Spokane.

Professor Fullmer sums up his conclusions as follows:

"Barrenness may be due first, to a deficiency in lime, potash and phosphoric acid; second, to their not being in an available form, or third, to adverse climatic conditions.

"Analytical results prove that western Washington soils will be greatly strengthened by the application of lime.

"The average percentage of lime and potash are higher and phosphoric acid lower in eastern than in western Washington.

"The lime percentages are lower in regions of abundant rainfall than in the dryer parts of the state."

ROAD-MAKING MATERIALS.

GENERAL STATEMENT.

The Construction and Care of Roads.

In the pioneer stage of development a community is compelled in its road making to use the material immediately at hand whether it be good or bad. For many years to come most of our country roads necessarily will have to be made of the materials over which they run, especially the cross roads which lead off from the main highways of traffic. In the case of the larger arteries of commerce, the leading roads which bind together our towns and cities, the time is now here when the question of proper construction and of proper materials for these highways should receive the greatest attention. Road making requires skill and training of a special kind, and should therefore be done under the direction of a competent engineer. One of the greatest mistakes which is made in the laying out of roads is to require that they follow without deviation the section lines. The community should be allowed to exercise the right of eminent domain in the location of roads. It is quite as important as in the case of railroads. It is a wasteful system to require that the roads zigzag around section lines, up hill and down hill, when a comparatively level grade may be easily obtained, usually on a more direct route. It is much cheaper for a community to buy up a desirable right-of-way than it is to have its traffic for an indefinite number of years compelled to make detours and climb steep hills simply for the purpose of keeping on section lines. When permanent improvements of a road are contemplated it is especially important that the best grades and the most direct route be found, otherwise the evil is practically placed beyond remedy for many years to come.

The initial cost of good roads is usually high, and their construction should not be undertaken in a haphazard manner. America is far behind Europe in the matter of highway construction, but this is a condition of affairs which it is earnestly hoped will speedily be changed. It is said that the roads in the mountain republic of Switzerland have much more gentle grades than

those of the prairie states of our own country. The system of building and maintaining roads which we use now is the same as that employed in Europe a century ago, when the roads came to be so bad that the various governments had to take the matter in hand. In England the work of constructing highways was placed in the hands of engineers like Macadam and Telford, with the result that a system of highways was built which has remained in excellent condition down to the present day. Methods similar to those employed in Europe will have to be used in this country before we can bring our highways into the same degree of excellence.

One essential thing in road construction is to have the road in such shape that it can be kept dry. The surface should be able to shed water, and ditches and culverts should be so placed that no water will be allowed to accumulate. In country districts the road should not be too wide; eight feet is usually wide enough. In making a macadam road the mistake is usually made of getting them too wide. After a road is well built care should be taken to keep it in good repair. Narrow tires on vehicles are very effective agents in destroying a road. In order to encourage the use of wide tires a number of states have offered a rebate on road taxes to all who will use them. It has been proven by a series of experiments that except in deep mud wide-tired vehicles require less power to pull them than do those with narrow tires. On a smooth hard road the advantage is found to be in favor of the wide tires. Wide tires act as road makers and narrow tires as road destroyers. The wide tires roll the road out smoothly and do not cut it into ruts.

Materials for Road Making.

For some years to come many of our roads will doubtless be made of common dirt or loam. A dirt road, if properly made and kept in good repair, has some advantages over a hard stone road in dry weather. It is not so wearing on vehicles or on the hoofs of horses. In wet weather a dirt road is the worst of all, and should be macadamized as soon as circumstances will permit. The best rock for this purpose is fine-grained volcanic rock, crushed into fragments not more than an inch and a half in diameter. This should be spread on the prepared roadbed in successive layers, each one rolled with a heavy steam roller

before the next layer is spread. The topmost layer should be made of the fine dust of the broken rock. It fills up all the interstices in the layers below and cements the whole mass together.

In order to make good road material, a rock should possess considerable hardness and toughness, combined with the power of cementing well when placed in a roadbed. Granite does not make a very good macadamizing material because the quartz contained in it crumbles under the impact of traffic and the other minerals scale off and weather quite rapidly. Limestone has great cementing power, but because of its softness it does not wear as well as some other rocks. Sandstone is quite useless for macadamizing purposes as it crumbles very easily and will not cement readily. Among volcanic rocks basalt is probably the best, as it is one of the very best rocks used in road construction. It is tough, durable, and cements well.

Glacial till which has not been exposed at the surface so as to become weathered makes very good road material. It is a mixture of clay, sand and gravel, and cements together readily. Sand, when used alone, is extremely poor material to use in the construction of a road, because it will not consolidate. Clean, rounded gravel is almost as bad. A gravel bank which looks brown or red should never be used on a road. Its color shows that it has been weathered and has lost the power of cementing together when put on a road. If coarse gravel is put through a crusher, it will often cement very well on account of the fresh, unweathered surfaces exposed. Pure clay is not a good road material, but when gravel, sand and clay are mixed together they make a firm, waterproof roadway that wears very well.

ROAD-MAKING MATERIALS OF WASHINGTON.

Washington possesses a large variety of the best materials used in building roads. Not only are these materials of a superior order, but they are widespread in occurrence and practically limitless in quantity. The lack of good materials for road construction can never be urged as an excuse for poor roads in Washington. In describing the road-making materials of the state it will be possible to mention only a few of the localities where these things occur.

WESTERN WASHINGTON.—Within the glaciated area of western Washington, which comprises all except the southwest cor-

ner of the state, glacial till occurs everywhere. A great deal of the till is good road making material. Where there is the right proportions of clay, sand and gravel with some cementing ingredient present it becomes very compact. In choosing material of this nature care should be taken to see that it is not too loose and incoherent and that it does not contain too large a proportion of clay. A bank which stands upright and when picked down falls in large masses without crumbling is the best. Within the glacial area sand and gravel are very abundant everywhere. As pointed out before, these alone are not very good for making roads. However, both are extensively used in making a foundation for vitrified brick pavements in the cities. There is a large sand and gravel plant operating at the water's edge near Steilacoom. The materials are washed and then sorted by means of revolving sieves into various grades of fineness.

Within the limits of the glacial region of western Washington, there are a number of localities where volcanic rocks suitable for macadamizing purposes crop out above the drift. Near the Port Orchard dry dock there is a quarry in basalt, near the water's edge, where rock for road building is taken out. It is crushed at the quarry and sent in scow loads to Seattle, Tacoma, and other cities about the Sound. Another quarry has been opened along the railroad track between South Seattle and Black River Junction. The rock here is mottled volcanic rock, probably andesite, and is rather too soft to be of very good quality for macadamizing. It is now being used in combination with other rocks for making concrete pavements in Seattle. Along the western side of Hoods Canal there are extensive outcrops of volcanic rock suitable for macadamizing purposes. Along the Grays Harbor branch of the Northern Pacific Railway a hard, compact, durable basalt outcrops at many places between Gate City and Aberdeen. It exists in large quantities, is very accessible, and is a road-making material of the very best quality.

At a number of places in western Washington limestone occurs which may have a large use in the road construction of the future. It is for the most part quite accessible and exists in ample quantities. Granite from Index is used very largely for street curbing in the cities about Puget Sound.

EASTERN WASHINGTON.—In eastern Washington the basalt of the great lava plans makes a first class macadamizing material. This is a part of the state which perhaps more than any other needs a system of good roads. The best farming sections of the state are located within the limits of the lava fields. In the Palouse country, about Walla Walla, and within the great bend of the Columbia, there is a large and increasing population depending upon agriculture. Wheat growing is the principal industry. During the summer months the roads are everywhere dry and in fairly good condition, but when the fall rains come and the farmer is ready to haul his grain to market the roads are usually all but impassible. When the lava finally weathers and decomposes it forms a finely powdered soil which accumulates to great depths in the valleys. When the soil becomes soaked with water there is apparently no bottom to the mud thus produced, and until it freezes or slowly dries up traffic throughout the rural districts is almost at a standstill.

A large part of the area embraced within the limits of the Columbia lava plain in this state is now so thickly populated and so prosperous that an extensive system of highway improvement should be inaugurated without any further delay. The basalt which is to be obtained everywhere makes the very best material, so that the construction of good macadamized roads would not be expensive. The rock would have to be crushed, spread in layers on the prepared road bed and rolled with heavy rollers. In this way a system of roads would be built which would be in good condition every day in the year. The saving in the expense of hauling the produce to market would more than suffice to build the roads and keep them in good repair.

North of the Columbia lava plain and east of the Cascades lies a region of ancient metamorphic rocks, granite, gneiss, schist, marble and slate with a ramifying system of trap dikes. It is a country of rolling hills given over chiefly to stock raising and mining. The towns are small and far apart, and not much in the way of a systematic improvement of the higways can be expected for some time. The trap dikes are pretty well distributed through the country rock and will furnish the very best material when the time comes to macadamize the roads. The streams all have terraces at various elevations above their beds and a great many of the roads follow along the tops of the terraces. The

gravel affords a natural drainage, so that the roads are likely to be in a good condition throughout the year. In some of the more promising mining districts it is imperative that first class roads be built in order to haul the ore out and get the supplies in to the mines. Mining camps as a rule are from their nature not as permanent as agricultural communities, so that the roads do not need to be of so permanent a nature.

In the vicinity of Spokane there are wide gravel plains where the roads possess a natural drainage so that no grading or side ditches are required. These gravels are relics of the glacial period, when the Spokane river was given a bigger load than it could carry and dropped some of it by the wayside. The gravel makes an excellent foundation for the vitrified brick pavements used in the city.

In the Yakima valley the underlying rock is sandstone, belonging to the Ellensburg formation, but there is abundant basalt and other volcanic rocks near at hand for macadamizing purposes. Some of the roads in the valley have been placed in very fair condition, and travel over them is not difficult even in bad weather. If the residents of this valley continue to pursue the same enlightened policy in a few years they will have a very good system of roads.

In the Kittitas valley the geological conditions are much the same as in the Yakima valley. Ridges of basalt surround the valley on all sides, so that the rock can easily be quarried out in a hundred different places. The sandstones which occur in the vicinity of Ellensburg are not good for road-building purposes, and certainly should not be used when basalt may be had so readily.

PETROLEUM.

GENERAL STATEMENT.

Conditions of Occurrence.

Petroleum in small quantities is very widely distributed throughout the sedimentary rocks all over the surface of the globe, but, like all other economic products of nature, it is valuable only when found in a sufficiently concentrated form. The finding of oil in small amounts on the surface or in the rocks of any locality is not usually of much importance as indicating the presence of commercial quantities. Until a well has been actually sunk and large quantities of oil found, there is always a considerable element of risk no matter how favorable the surface indications may be.

Before going to the expense of drilling it is well to know just how much importance can be attached to surface indications. The presence of oil as a film on the surface of water does not count for much unless it is in large quantities. Seepages may or may not be an indication. Professor Edward Orton * says: "Along the extensive northern and western outcrops of the great Ohio shale through western New York, Ohio, Kentucky and Tennessee, oil and gas springs are everywhere found, but the supplies are invariably small in quantity, and there are no indications of storage on the large scale such as would justify the application of the term 'reservoirs' to the formation." Very often the seepages merely show that the oil has found a means of escape to the surface and that none will be found under pressure in the rocks. Besides, oil is not the only substance that forms an iridescent film on the surface of water; certain iron compounds and organic substances have the same effect. Even when the seepages of oil are unmistakable, it should be borne in mind that the presence of small quantities of petroleum in the stratified rocks is the normal condition in nature, and that it is only where the conditions are exceptionally favorable that the oil is concentrated.

* Edward Orton: Petroleum and Natural Gas. Kentucky Geological Survey, 1891.

No importance whatever can be attached to the topography of the locality as an indication of oil except where the hills and the valleys conform to the folds of the rocks. It is not likely that in the supposed oil regions of the state there is a conspicuous connection between the rock structure and the land features, so that in the absence of surface indications oil is just as likely to be found by drilling on a hill top as in a valley. Wherever possible the folds of the rocks should be determined from the surface outcroppings, and the well sunk on an anticline or arch. Since oil is lighter than water it rises to the highest part of the fold and gives place to water below. In the Pennsylvania oil fields all the successful wells are located on the arches of the folds.*

Before petroleum can accumulate in large quantities in one place three conditions are usually considered necessary. 1st. There must be a source of the petroleum; that is, there must be strata containing organic matter wherein the chemical processes may take place by which vegetal and animal tissue is changed into petroleum. 2d. There must be a reservoir of porous rock to contain the oil after it is formed. This is usually sandstone or conglomerate. In the Ohio and Indiana oil regions the reservoir is Trenton limestone. It is only when the limestone has become changed into dolomite that it becomes porous enough to act as a reservoir. Owing to local conditions in this state sandstone is most likely to act as a reservoir. 3d. There must be impervious strata above the oil-bearing beds in order to prevent the oil from escaping to the surface. Shale or other close grained rock usually occupies this position in the oil regions. To these three conditions there is usually supplemented a fourth, namely, that the rocks must be thrown into folds so that the oil can collect in the arches of the folds.

Origin of Petroleum.

Petroleum is formed by the decomposition of vegetal and animal remains embedded in the sedimentary rocks. Such rocks are formed by the accumulation of sediments on the floors of seas and lakes. Along with the inorganic sediment carried down by the streams there is always a considerable amount of organic material carried also. This material, together with the

*I. C. White: Geology of Natural Gas. Science, June 26, 1885.

remains of animals and plants which live and die in the sea, is gradually covered up by succeeding sediments. Any kind of organic matter when exposed to the air quickly decomposes, but when it is buried beneath water, and hence is very well protected from the air, decomposition goes on with extreme slowness, so that the resulting chemical products are of a different nature from those formed in the air. It is not possible to reproduce in the laboratory the conditions under which petroleum is formed; in this case we connot imitate the processes of nature. It is believed, however, by all who are recognized authorities on the subject, that oil is formed by the decomposition of organic matter contained in the sediments which have been deposited on the sea floor.

Oil has been found in nearly all the geological horizons from Silurian to late Tertiary. The Pennsylvania oil fields are in Devonian rocks, the Ohio and Indiana fields are in Silurian. The Russian oil fields, on the Caspian sea, are in Tertiary rocks. In California, where the conditions most nearly resemble those found in our own state, most of the oil is found in rocks of Miocene or middle Tertiary age. Tertiary rocks containing petroleum are known to exist all the way along the Pacific coast from South America to Alaska. In the California oil districts the rocks are sharply folded; in some of the wells the strata are almost vertical. The oil, too, is heavier than the eastern article and has an asphalt base.

PETROLEUM IN WASHINGTON.

In considering the probability of obtaining oil in Washington, it is not possible to discuss the state as a whole. Its geology is so diversified that it will have to be treated in sections. By a process of elimination, those portions of the state where the conditions do not admit of the formation and accumulation of oil will be first mentioned and set aside, until the field is narrowed to those areas where the conditions are such that oil may exist, and which may therefore afford proper prospecting ground.

Beginning with eastern Washington, the area lying between the Cascade mountains on the west and the Idaho boundary on the east, and between the Spokane and Columbia rivers on the north and Oregon on the south, forms part of the great Columbia basalt lava field. In its larger features it is approximately a

level plain, but is worn locally into hills and deep canyons. In the southern part of the area the lava is several thousand feet in thickness but gradually thins out to the northward until it is not more than three or four hundred feet thick. In several places Snake river has cut its canyon down through the lava and exposed the underlying rock, which is granite. Along the Washington-Idaho boundary the lava may be seen lying directly upon old crystalline rocks. In several places in the lava field similar crystalline rocks may be seen rising above the lava in the form of hills or buttes. Steptoe butte in Whitman county is an example. On the northern and western side the lava there may also be seen overlying crystalline rocks of very ancient origin.

If oil originates from the decomposition of organic remains embedded in sedimentary rocks, as is held by all whose authority on the subject is recognised, it is clear that none need be looked for in the region just described. All the evidence goes to show that previous to the outflow of the lava the region consisted of granite, gneiss, schist, and other rocks of similar nature. Then the lava came in successive overflows and gradually submerged valleys and hills until finally the whole country was one vast level expanse of basalt. This part of the state may therefore be eliminated from the list of possible oil bearing regions.

North of the Columbia lava plain is the region known as the Okanogan highlands. It includes practically all of eastern Washington north of the Spokane and Columbia rivers. The rock is mainly of ancient crystalline type, mostly granite, gneiss, and schist, with occasional small areas of sedimentary rocks of later times. It is evident at once that it is not worth the while to look for oil in the rocks of the Okanogan highlands.

In the Cascade mountains the rocks have been folded, crushed and broken so badly that any oil which they might have held at one time has long since escaped. In the oil fields of Pennsylvania, Ohio and Indiana the evidence seems to show that a moderate amount of folding in the rocks is necessary for the accumulation of oil. When the folding and crushing have been carried to an extreme point, however, the consolidation or metamorphism of the oil bearing rock forces out the oil and it escapes through the fissures which are formed. For this reason we would also

exclude the Cascade mountains from the list of places where oil is at all likely to be found.

The Olympic mountain region would be excluded for the same reason as in the case of the Cascades. This refers, of course, only to the higher parts of the mountains which are composed exclusively of igneous rocks. In the lower foothills, where sedimentary strata occur, the conditions are often favorable for oil accumulation.

This process of exclusion leaves as possible oil-bearing territory all of western Washington, with the exception of the higher parts of the Olympic mountains mentioned above. It will be seen by referring to the geological map which accompanies this report that with the exception of the San Juan islands, which are of Cretaceous age, all of the rocks embraced in the area under consideration belong to the Tertiary period. They are, therefore, of the same age as the rocks of the California oil fields.

It is probable that during Tertiary times the region now forming western Washington was the bed of a shallow sea. The Olympic mountains doubtless formed an island in this sea. Sand and mud accumulated to great depths on the sea floor, and there was buried within these sediments the remains of sea animals and plants as well as the vegetal matter brought down to the sea by the rivers. By processes known only to nature this organic matter may have been turned into petroleum just as it has been known to do under similar conditions in the great oil regions. After the sediments had accumulated to a depth of many thousands of feet and had been changed into solid rock, there came a gradual upheaval by which the sea floor was elevated until it became a part of the land. This elevation was accompanied by great lateral pressure which folded the rocks and raised the mountains to their present height. Since that time the streams have eroded away a great part of these sedimentary rocks and carried their constituents again into the sea.

During the Glacial period all but the southwestern part of this region was covered with ice several thousand feet thick. Buried within the drift material left by the glaciers are beds of vegetal matter more or less decomposed. In some instances, perhaps from this vegetal matter, a little petroleum may have been formed. If such were the case it would account for many

of the so called surface indications of petroleum found in the glacial drift about Puget sound. Oil formed in glacial drift can never occur in large quantities; for this reason it is unwise to pay any attention to surface indications found in glacial material. There is usually so much clay present in the drift as to preclude any possibility of the oil having seeped from the bed rocks lying below, especially when the drift has a thickness varying from 500 to 1000 feet, as is the case in western Washington.

The best indications of oil in the state have been found along the coast between Grays Harbor and Cape Flattery. As far as known, this part of the state has never been carefully studied by a geologist, and most of the information concerning it consists of the reports brought out by prospectors and others, together with the samples of rock which they have brought along with them. Some of the specimens of rock are composed very largely of marine shells. These are of Tertiary age, probably Miocene. The rocks are mostly light colored sandstone and are considerably folded in places. They lie against the western flanks of the Olympic mountains which, from various reports, seem to be composed in large part of rocks of much more ancient origin. It is said that over wide areas the sandstone, when broken with a hammer, gives out a strong odor of oil. Clay beds strongly impregnated with petroleum are also to be found along the coast for many miles.

At least three wells are now being drilled in this part of the state. [March, 1902]. A company known as the Olympic Oil Company is drilling a well near Copalis Point, Chehalis county. They are said to be down a distance of between eight and nine hundred feet and to have good indications of oil. Another company, the Eldorado, is also drilling on Copalis river about two miles from the Olympic company's well. On the authority of Mr. George Wilkening, the president of the company, they are now down a distance of one hundred feet and are sinking as rapidly as circumstances will permit. Farther north along the coast the Lapush Oil Company is drilling a well near the little Indian village of Lapush, at the mouth of the Solduck river, in Clallam county. The rock where they are drilling is a light colored sandstone lying upon conglomerate and dipping north-

east at an angle of about forty-five degrees. Good surface indications are said to be found in this neighborhood.

The work of drilling along this part of the coast is a slow process on account of the difficulty and delay in obtaining suitable tools. All drilling tools have to be obtained from San Francisco, and vexatious delays have been the rule.

Between Tenino and Grand Mound, in Thurston county, the Puget Sound Petroleum Company have reached a depth of about a thousand feet, and are still continuing operations. The Pacific Oil Wells Company of Tacoma sunk a well at Tacoma and another at Des Moines, King county, but finally abandoned both. They are now drilling a third well at Happy Valley, near Fairhaven, Whatcom county. They are now down a distance of one thousand feet and still drilling. They claim to have passed through three layers of oil-bearing sand and at the depth of about nine hundred feet to have pumped up a small quantity of oil. For the first one hundred feet the drill passed through glacial drift, but since that the formation has been mostly sandstone and shale. A company known as the Seattle and King County Oil Company are drilling a well near South Park on the western side of the Duwamish valley. They have been hindered by a number of accidents and delays, but are still sinking and at last reports had attained a depth of seven hundred feet without having found as yet any indications of oil.

This completes the list of companies which are carrying on active operations in the state, as far as known. A well was sunk near Stanwood station, Snohomish county, about ten years ago, by Mr. John E. McManus. A depth of about nine hundred feet was attained, but owing to difficulties of drilling it was finally abandoned. Other wells have no doubt been sunk at different places, but the data regarding them is not at hand.

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WASHINGTON

GEOLOGICAL SURVEY.

HENRY LANDES, STATE GEOLOGIST.

VOLUME I.

ANNUAL REPORT FOR 1901.

IN SIX PARTS.

PART IV.

THE IRON ORES OF WASHINGTON.

BY S. SHEDD.

THE COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES.

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ILLUSTRATIONS.

PREFACE.

In the IRON ORES OF WASHINGTON, by S. Shedd, the subject is treated more exhaustively than is the case with any other part of this report. A description is given of all the known occurrences of iron in the state, together with complete analyses and comparisons with ores found elsewhere. In the field work necessary to the preparation of the article on iron ores, two seasons were occupied by Professor Shedd and his assistants. The field work was all done prior to the inauguration of the State Geological Survey, and the entire expense of it was borne by the State Agricultural College and School of Science.

The article on the COAL DEPOSITS OF WASHINGTON, by Henry Landes, is a brief description of the coal fields and coal mines of the state. While the general geology of the subject is touched upon, along with the extent of the coal areas, etc., the commercial phase of the subject receives the most emphasis. At the present time coal constitutes by far the most important mineral resource of the state, and the treatment accorded it in this report is regarded as wholly inadequate. The present article is but a temporary treatment which it is planned to replace by a thorough and extended one a little later.

PLANT OF PACIFIC STEEL COMPANY, IRONDALE.

THE IRON ORES OF WASHINGTON.

BY S. SHEDD.

NOTE.—The work of preparing this report on the iron ores of Washington was begun in the summer of 1899, under the direction of the Board of Regents and the president of the Washington Agricultural College and School of Science, and the entire expense, for the work, has been defrayed by the College. The summer of 1899 and a part of the summer of 1900 was spent in the field visiting the different localities, collecting samples, and studying the different deposits. The analyses of the Washington ores given herein, with the exception of those taken from a manuscript report by R. H. Stretch, E. M., and one from Willis and Smith's paper on the Clealum district, were made by myself or by the chemists of the department of chemistry in the Washington Agricultural College and School of Science.

While I take sincere pleasure in acknowledging the kind and ready assistance rendered me by those upon whom I had occasion to call for help or information of any kind, I am especially under obligations to Messrs. Thomas Cooper, J. J. Conner, Chas. Denny, and H. L. Blanchard for the interest shown and the help given, and I desire to express to them, especially, my most hearty thanks and appreciation of their kindness.

DISTRIBUTION AND COMBINATIONS IN WHICH IRON OCCURS.

GENERAL STATEMENT.

Iron is one of the most widely distributed of all the different minerals. It seldom occurs in the native state, but is combined with different elements, oxygen being the most common one, and in this form it is a very important factor in giving the color to the various rocks and soils. It combines with sulphur to form sulphides and is then known as iron pyrites and in this form it is very important, not for the manufacture of iron, but from the fact that it frequently carries more or less of the precious metals, such as gold and silver. Iron is also found in combination with other elements, such as phosphorus, silica, titanium, arsenic, etc.

THE ORES OF IRON.

While iron occurs in combination with many different elements, there are only a few forms that are used in the manufacture of iron. The valuable ores commercially are the magnetites, the hematites, the limonites, and the carbonates.

Magnetite is an anhydrous oxide of iron and when perfectly pure has the following per cent. of iron and of oxygen: Magnetite (Fe_3O_4) metallic iron, 72.4 per cent., oxygen, 27.6 per cent.

While theoretically magnetite should contain 72.4 per cent. of iron, practically very little of it does contain so high a per cent. on account of the impurities that occur with it. The common impurities are such minerals as quartz, feldspar and hornblende. Magnetites always give a black streak and differ in this respect from the hematites which have a red or brown streak. The magnetites also have the property of magnetism; that is, they are attracted by a magnet.

Of the different varieties of iron ores mined in 1899, only 1,727,430 long tons, or 7 per cent. was magnetite.*

Hematite is an anhydrous oxide of iron having, when pure, the following composition: Hematite (Fe_2O_3), oxygen 30 per cent., iron 70 per cent.

This is the most important ore of iron and is the most widely distributed of any of them, being disseminated in greater or lesser amounts in the soils and nearly all rocks; in fact most soils and rocks owe their color to iron. It is not confined to rocks of any particular geological age or to rocks of any particular kind. There are several different varieties of hematite, such as specular iron, red ochres and clay iron stone, but all of these varieties when pulverized give the characteristic red powder which distinguishes them from the other oxides of iron.

"The specular variety is mostly confined to crystalline or metamorphic rocks, but is also a result of igneous action about some volcanoes, as at Vesuvius. Many of the geological formations contain the argillaceous variety of clay iron stone, which is mostly a marsh formation, or a deposit over the bottom of shallow, stagnant water; but this kind of clay iron stone, that giving a red powder, is less common than the corresponding variety of limonite." (Dana, Edward S.: Text Book of Mineralogy, p. 335.)

In 1899 there was mined in the United States 20,004,399

*21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 83.

long tons of red hematite, which is 81 per cent. of all the iron ore mined in the United States that year.*

Limonite, or brown hematite, is a hydrous oxide of iron having the following composition: Limonite ($2\ Fe_2O_3$, $3\ H_2O$) oxygen 25.7 per cent., iron 59.8 per cent., water 14.5 per cent.

This ore is a secondary product, in all cases, and is derived from the alteration of other ores, minerals or rocks containing more or less iron. The variety known as bog ore is the most widely distributed, occurring in many places in the United States. It has been formed in marshy places and has been carried in solution, by streams, into these places.

This ore is very apt to contain more impurities, such as silica, clay, phosphates, oxides of magnesium and other substances of this nature than magnetite or hematite. Limonite is distinguished from the other oxides of iron by its brown color when finely powdered.

The brown hematites, in 1899, amounted to 2,869,785 long tons, or 11.6 per cent. of all the iron ores mined in the United States for that year.†

Siderite, or spathic iron, is the protocarbonate of iron and has the following composition: Siderite ($Fe\ CO_3$) carbon dioxide 37.9, iron protoxide 62.1, metallic iron 48.2 per cent.

The spathic ores are the lowest in iron of all and are least important, as shown by statistics of production for 1899, there being only 81,559 long tons mined or .33 per cent. of the iron ore produced during that year.‡

The following table, taken from the Twenty-first Annual Report of the United States Geological Survey, Part VI, Mineral Resources, page 35, gives the amount of the different classes of iron ores mined in the United States for eleven years from 1889 to 1899, inclusive, with the per cent. of each class for the eleven years and also for the last year 1899. This table is given here for comparison and shows that the most important iron ore has not been found in Washington in anything but small quantities up to the present time.

* 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 32.

† 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

‡ 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p 33.

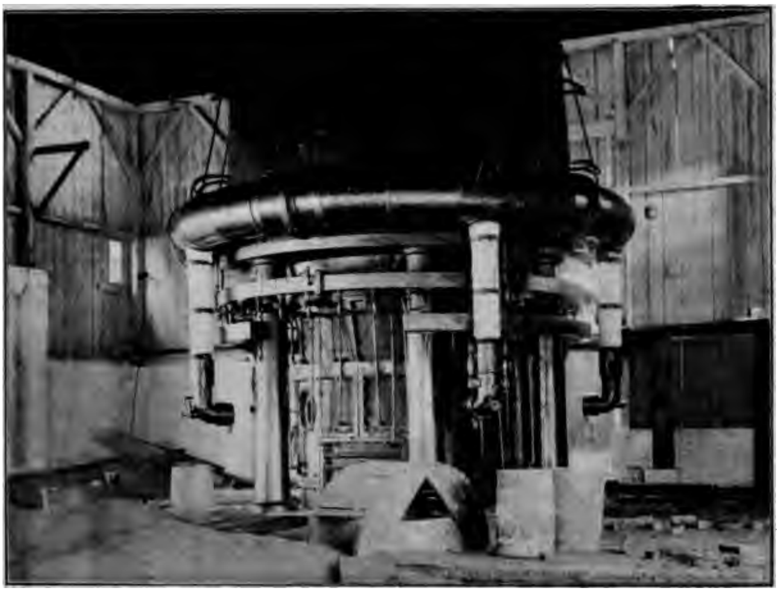
PRODUCTION OF IRON ORES IN THE UNITED STATES BY CLASSES.

YEAR.	*Red hematite, long tons.*	*Brown hematite, long tons.*	*Magnetite, long tons.*	*Carbonate, long tons.*	*Total, long tons.*
1889	9,056,288	2,523,087	2,506,415	432,251	14,518,041
1890	10,527,650	2,559,938	2,570,838	377,617	16,036,043
1891	9,327,398	2,757,564	2,317,108	189,108	14,591,178
1892	11,646,619	2,485,101	1,971,965	192,981	16,296,666
1893	8,272,637	1,849,272	1,330,886	134,834	11,587,629
1894	9,347,434	1,472,748	972,219	87,278	11,879,679
1895	12,513,995	2,102,358	1,268,222	73,039	15,957,614
1896	12,576,288	2,126,212	1,211,526	91,423	16,005,449
1897	14,413,318	1,961,954	1,059,479	83,295	17,518,046
1898	16,150,684	1,989,681	1,237,978	55,373	19,433,716
1899	20,004,399	2,869,785	1,727,430	81,559	24,683,173
Totals	133,836,710	24,697,700	18,174,066	1,798,758	178,507,234
Percentages of totals for eleven years	75.00	13.8	10.2	1.00	100.00
Percentages of total for 1899.	81.04	11.63	7.0	0.33	100.00

THE RELATIVE VALUES OF IRON ORES.

The value of an iron ore does not depend entirely upon the amount of iron it contains, but upon the other substances, and amounts of them, found with it. The most common injurious substances are phosphorus and sulphur. There are, however, a number of other substances that occur as impurities, such as titanium, silica, alumina, calcium, and magnesia. These latter, however, can hardly be considered as injurious substances in the sense of injuring the pig iron, but rather as lowering the per cent. of iron. They also determine the fluxes needed. Sulphur and phosphorus, however, act in an entirely different way, and even a small amount of either of these injures the ore for a Bessemer pig iron.

Again its location is an important factor in determining the value of an iron ore, so that an ore may be quite high in the per cent. of iron it contains and still not be of any value, simply because it would cost too much to get it to market. Then again the nearness of fuels and fluxes come in to regulate its value. Take for instance Pennsylvania, which ranks first in the product of pig iron, producing in 1899, 6,558,878 long tons, or about one half of the entire product of the United States for that year, but which ranks fifth in the production of iron ore. This comes from the fact that, while Pennsylvania does not have as large deposits of iron ore as some of the other states, she does have very extensive beds of good coal, and it has been found cheaper,



FURNACE, PACIFIC STEEL COMPANY, IRONDALE.

CHARCOAL KILNS, PACIFIC STEEL COMPANY, IRONDALE.

as a general thing to ship the ore to the fuel than to ship the fuel to the ore.

THE HISTORY OF IRON MINING AND MANUFACTURE IN WASHINGTON.

The first furnace for the manufacture of pig iron in Washington began operation in the fall of 1880. This furnace was located at Irondale on Port Townsend bay about four miles south of the city of Port Townsend. The furnace had a daily capacity of ten tons and was a hot blast charcoal furnace. After being operated six months this furnace was found to be unsatisfactory, abandonded, torn down and a furnace with a capacity of fifty tons daily was constructed in its stead. On account of the very refractory nature of the ore being used this new furnace did not meet expectations, and after being operated for several months was reconstructed and then operated very successfully, as far as the grade of pig iron produced was concerned, about six months each year until 1891, when the furnace was closed down permanently.

The Irondale plant was first built for the purpose of using a deposit of limonite or bog ore which occurred south of there in the Chimacum valley, but the iron produced was found to be of a rather poor quality and the deposit proved to be very limited in quantity, so a magnetite found on Texada island, a British island situated in the Straits of Georgia, about one hundred and twenty-five miles northwest of Port Townsend, was mixed with the bog ore. It was found that a mixture of these two ores produced a very high grade of pig iron, but owing to the fact that there was an import duty of seventy-five cents a ton on the Texada ore, and charcoal being expensive, on account of having nothing but soft wood from which to make it, coke twelve dollars a ton, labor high, and the price of iron low, it was found to be a losing proposition, and it is claimed that every day the furnace was operated it was at a loss, and hence in 1891 it was closed down and had been allowed to go to decay until March, 1901, when Pennsylvania capital became interested in the matter and what is known as the Pacific Steel Company was formed and obtained control of the old Irondale plant for a consideration of $45,000. This new company immediately began the work of putting the plant in first class condition again and have

expended about \$100,000 on the property. December 15, 1901, the plant was again put in operation.

The new plant has a stack 60 feet high, 12 feet in the bosh, 6 feet on the crucible, and a capacity of about 50 tons a day. The power to drive the machinery for hoisting and crushing the ore will be furnished by a battery of four steam boilers, while large blowing engines will furnish the blast for the furnace.

At the present time ores from Texada island and from Hamilton, Skagit county, are being used. These two grades of ore are mixed in the proportion of 700 tons of Texada ore to 50 tons of Hamilton ore or about 93 per cent. Texada and 7 per cent. Hamilton. The principal flux used is limestone from the Roche Harbor lime works. The following analysis shows the composition of this limestone: Calcium carbonate, 98.32 per cent.; iron and alumina, 1.13 per cent.; silica, .44 per cent.; phosphorous, .11 per cent. In addition to the limestone a small amount of sand is used.

A little coke from Cokedale has been used, but the principal fuel is charcoal, and this is produced by the company's own charcoal plant on the premises. There are, for the burning of this charcoal, twenty kilns each 30 feet high and 30 feet in diameter at the base and holding 75 cords of wood each.

These twenty kilns will burn 180 cords of wood a day and have a total capacity of 180,000 bushels of charcoal per month. A sawmill and splitting-machine have been installed, so that the company now buys the logs and makes its own cordwood at the works. Machinery is being installed also for conveying automatically the wood to the kilns.

The ores from Texada island and from Hamilton are loaded on scows, transported to the plant and dumped into the bunkers. From the bunkers the Texada ore is hauled in small cars into the yard, where it is arranged in large heaps and roasted to get rid of sulphur and also to make it more easy to reduce in the furnace. Castings are made three times a day; that is, every eight hours. The pig iron at present is sold to the various foundries around Puget sound, Oregon and British Columbia. The company, however, expects in the near future to ship to San Francisco.

The old plant when in full operation employed altogether, in the mines, cutting wood and burning charcoal, and at the fur-

nace, about 250 men. The new plant will employ directly and indirectly about 300 men.

There are a number of places in the state where considerable development work has been done, but the bog ores at Irondale are the only ones from which iron has been produced. From 1889 to 1892, inclusive, development work was quite vigorously pushed in the Clealum district in Kittitas county by a Scotch company who were contemplating the building of an extensive plant at Kirkland, on the shore of Lake Washington, but for some unknown reason work was stopped in 1892, and nothing has been done since.

In 1881 Mr. F. M. Guye discovered and located iron mines in the Cascade mountains, one and one-half miles northwest of Snoqualmie pass on the south fork of the Snoqualmie river. Soon after this he also found another deposit about six miles northeast of North Bend, the present terminus of the Snoqualmie branch of the Seattle & International Railroad.

Other properties have been located in the Snoqualmie pass district and some development work done, but at the present time (1901) nothing is being done toward developing any of these properties.

About 1881 iron ore was discovered by Mr. J. J. Conner, in Skagit county, near Hamilton on the Skagit river. Since that time these same deposits have been traced, and locations made, for several miles along the south bank of the Skagit river above Hamilton, and the ores occurring near Marble Mount are probably a continuation of these same Hamilton ores. Considerable development work has been done on some of the properties in this district, but no very great depth has been reached.

In 1881 two tons of the iron ore from the Hamilton district were sent to Tacoma and tests were made at the smelter there, and a company formed to build a plant at that place. In 1887 twenty tons were tested at Irondale. This ore was sent by J. J. Conner, of Hamilton.

About eleven miles northwest of Hoodsport in Mason county, a number of iron mines have been located and some development work done.

In Stevens county iron ores occur near Colville and Valley, each of which is on the Spokane Falls & Northern Railroad. At one time the deposits near Valley were being worked and the ore

shipped to Tacoma to be used as a flux in the smelter located there.

THE DISTRIBUTION OF IRON ORES IN WASHINGTON.

Iron ore occurs in many places in the state of Washington, but only in a few places is there any prospect of the known deposits ever being utilized for the manufacture of iron. There may, however, be many mines located in the future that we know nothing about at present, as there is a large part of the state that has not been very thoroughly prospected as yet, and for that reason we do not know what we may have in the way of iron ore.

The principal known deposits are in the following counties; Skagit, King, Kittitas, Stevens, and Mason.

Bog ores are found in a number of places in the following counties; Whatcom, Clallam, Spokane, Whitman, Thurston, and Jefferson.

ANALYSES OF WASHINGTON IRON ORES.

No.	Locality.	Iron	Silica (SiO_2)	Phosphorus (P)	Sulphur	Insoluble residue	Alumina (Al_2O_3)	Manganese (Mn_2O_3)	Calcium ($CaCO_3$)	Analyzed by
	Olympic Mountains, Mason county—									
1..	Ore from cabins	16.34	....	0.13	....	24.20	8.00	27.14	11.28	Fulmer.
2..	Pomeroy mine	19.25	....	Trace.	....	70.50	.65	.32	1.13	"
3..	Pomeroy mine	4.13	....	0.21	....	19.04	6.91	42.58	6.00	"
4..	Pomeroy mine, 4,000 feet above river	10.66	....	0.16	....	27.39	2.33	5.18	49.16	"
5..	Hoodsport mine	10.20	....	0.16	....	11.64	1.24	1.58	70.34	"
6..	Hoodsport mine	13.76	....	0.20	....	29.35	....	4.18	36.91	"
	British Columbia—									
7..	Texada island	67.91	2.96	Trace.	....	....	....	....	1.05	"
	Black Hills, Chehalis county—									
8..	Float	52.31	....	"	....	13.04	1.06	.14	....	"
9..	Float	48.18	....	....	....	25.02	.20	.23	....	"
10..	Black sand	43.72	....	....	....	24.14	11.65	.18	....	"
	Hamilton District, Skagit county—									
11..	From tunnel on Inaugural	43.89	19.98	.11	....	....	3.30	12.30	3.98	Thatcher.
12..	Hamilton mine	32.14	30.53	.31	.06	....	7.25	11.74	5.82	"
13..	Hamilton mine, near middle of vein	36.72	20.24	Trace.	....	....	7.40	13.04	9.77	"
14..	Inaugural mine, surface	31.08	31.82	.18	....	....	6.79	14.28	5.83	"
15..	Hamilton, near wall	33.88	32.94	1.06	.16	....	2.57	7.31	8.81	"
16..	Inaugural	43.91	18.36	.69	....	....	3.09	12.00	8.92	"
17..	Treadwell mine	43.72	22.85	.44	....	....	3.17	8.08	3.78	"
18..	Pittsburg mine	32.92	28.05	.31	....	....	8.43	8.11	8.06	"
19..	Pittsburg, upper ledge	29.11	32.46	.20	....	....	8.56	13.11	6.71	"
30..	Inaugural, from dump	39.44	20.84	.69	None.	....	3.76	3.67	8.63	Shedd.
33..	New opening	49.60	....	.59	"	27.04	None.	.19	3.95	Fulmer.
34..	Vein No. 5	42.43	24.13	.64	.25	....	9.54	Not det.	Not det.	Shedd.
	Snoqualmie Pass, King county—									
20..	Guye mine	67.13	3.60	None.	....	....	None.	None	None	"
21..	Guye mine	66.82	4.20	"	....	....	"	"	"	Fulmer.
35..	Denny mine	62.45	5.78	"	.21	....	5.34	"	"	Shedd.
36..	Denny mine	68.54	1.89	"	.25	....	.28	"	"	"

ANALYSES OF WASHIGTON IRON ORES—CONCLUDED.

No.	Locality.	Iron	Silica (SiO_2).	Phosphorus (P)	Sulphur	Insoluble residue	Alumina (Al_2O_3)	Manganese (Mn_2O_3)	Calcium ($CaCO_3$)	Analyzed by.
	Clealum District, Kittitas county—									
22..	Emerson mine	47.10	15.58	None.	None.	....	1.92	Not det...	Not det...	Shedd.
23..	Hard Scrabble mine	47.87	14.00	"	....	....	6.02	"	"	"
24..	Pebbly ore	46.24	7.50	"	Trace.	....	25.95	"	"	"
25..	Laminated ore from near Camp creek	47.10	8.70	"	"	....	12.22	"	"	"
26..	Laminated ore from near cabin	51.68	7.84	"	"	....	5.67	"	"	"
27..	Massive ore from near cabin	54.40	5.54	"	"	....	8.29	"	"	"
28..	Massive ore from Camp creek	51.13	6.94	"	"	....	14.23	"	"	"
29..	Best laminated ore from Camp creek	57.12	5.68	"	"	....	4.80	"	"	"
	Colville and Valley Districts, Stevens county—									
37..	Silver King mine	67.56	1.66	"	.38	....	None.	"	"	"
38..	Silver King mine	68.10	1.12	"	.25	....	"	"	"	"
39..	I. X. L. mine	56.58	4.49	.31	.32	....	2.00	"	"	"
40..	I. X. L. mine	50.48	14.90	.30	.32	....	2.48	"	"	"
41..	Capital mine	59.19	5.80	.16	.33	....	1.85	"	"	"
42..	Vigilant mine	58.33	3.54	.22	.21	....	3.18	"	"	"
44..	Mineral point	50.05	10.12	.20	.42	....	17.23	"	"	"
	Irondale District, Jefferson county—									
31..	Bog ore	53.67	....	1.09	Not det.	9.67	None.	.20	.95	Fulmer.
32..	Bog ore with gravel	28.48	....	.17	"	40.85	"	.92	2.10	"
	Cheney District, Spokane county—									
43..	Bog ore	35.12	16.30	.31	.19	....	10.94	Not det...	Not det...	Shedd.

THE CHARACTER AND COMMERCIAL VALUE OF THE IRON ORES OF WASHINGTON.

VARIETIES OF ORES.

The iron ores of Washington are magnetites, hematites, limonites, or hydrous sesquioxide of iron, known commercially as brown hematite, and mixtures of hematite and magnetite. The Snoqualmie pass ores are the only true magnetites while the Clealum, Hamilton and a part of the Stevens county ores are mixtures of magnetite and hematite. The Jefferson county ores, and part of the Stevens county ores, are limonites or bog ores. In several other places in the state the bog ores have been found in small quantities but they are of no commercial importance. The iron ore in Mason county is quite largely a hematite but most of it is of very little commercial value. In the Clealum district there is some quite strong lodestone ore.

COMMERCIAL VALUES.

One of the most important questions in connection with the commercial value of an iron ore is whether or not it is suited for the manufacture of Bessemer steel. This point is determined quite largely by the amount of phosphorus the ore contains, and the extreme limit has been placed at .05 per cent. for an ore that contains 50 per cent. of iron. While it is true that perhaps the question of the amount of phosphorus is one of the most important ones, it is necessary, of course, that the ore should have iron enough to make it profitable to work it and that the amount of silica, sulphur, and other impurities must be small enough so as not to injure it. The amount, however, of sulphur or silica allowable in a Bessemer ore is considerable more than that of phosphorus. It will be found by examination of the table, given on a following page, of analyses of ores from some of the different mines in the United States and Cuba that most of the ores are non-Bessemer ores. These ores, however, are used for making the commoner grades of iron but would not bring so high a price in the market as the Bessemer ores.

The accompanying table of analyses of Washington iron ores shows that they range in phosphorus from nothing to 1.09 per cent. As far as the per cent. of phosphorus is concerned a few of them, as far as other impurities also are concerned, would

be classed as Bessemer ores, but the larger part would be non-Bessemer. In some cases where the silica is within the Bessemer limit there is quite a large amount of alumina and that in connection with the silica would probably exclude those ores from the Bessemer class. Some of the ores contain a high per cent. of manganese and quite a number of them have from 7 per cent. to 14.28 per cent., while in one instance as high as 42.58 per cent. was obtained so that some of these might be valuable for the manganese they contain, provided they occur in anything like large bodies.

As regards their per cent. of iron the Washington ores range from 28.48 to 68.54 per cent. In taking the samples for anlyses the intention was to get average samples, but as on all the properties, with one or two exceptions, very little work has been done, it was a difficult matter to sample systematically and I presume the analyses show the per cent. of iron to be a little above the average of the whole deposits. The analyses show that with the exception of a few samples from one particular locality, and which were known to be of no value as iron ores before the analyses were made, that very few of the ores have less than 35 per cent. of iron and quite a good many of them have from 40 to 60 per cent.

In their contents of silica the Washington ores have as wide a range as they have in their contents of iron. The table of analyses shows the silica to range from a little less than 2 to a little less than 33 per cent. The amount of silica allowable in an iron ore is determined somewhat, of course, by the amount of iron the ore contains but in a general way 15 per cent. is given as about the limit. The analyses show that quite a good many of the Washington ores contain less than 15 per cent. of silica while there are a number of them that contain more than 15 per cent. of silica. A mixture of these two grades might be made in such proportions as to keep the silica below the limit and in this way considerable at least of the ore high in silica might be used.

In their contents of sulphur the Washington ores range from nothing to .42 per cent., which is really quite low and in fact much lower than that of many other ores that find a ready market.

As shown by the analyses a number of the Washington ores contain a large per cent. of alumina ranging from practically none to as high as 14.23 per cent. This large amount of

alumina in an iron ore is very uncommon and so much of it would be injurious to the ore.

SUMMARY.

The above facts show the iron ores of Washington, as far as their commercial value is concerned, to be principally non-Bessemer, but a few of them are Bessemer in qualitity. In iron they vary from 28.48 to 68.54 per cent.; in silica they vary from 2 to 33 per cent.; in alumina some of them run as high as 14.23 per cent.; in sulphur they are usually low; a few of them contain considerable manganese. The alumina and silica would have about the same effect or require about the same treatment, and taking the two together in some of the ores the per cent. would be very high.

The following table, taken from Vol. 1 of the Annual Report of the Arkansas Geological Survey for 1892, p. 15, comprising a number of analyses of iron ores from well know mines in the United States and Cuba, is given for comparison with the analyses of Washington ores:

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA.

No.	Locality.	Kind of ore.	Iron	Silica	Phosphorus	Sulphur	Analyzed by—
1	Tilly Foster mine, Putnam county, N. Y	Magnetite	48.91	12.18	0.015	0.548	Whitfield.
2	Crown Point, Essex county, N. Y	Magnetite	63.80		0.030		Richmond.
3	Crown Point, Essex county, N. Y	Magnetite	52.25		0.107		Richmond.
4	Moriah (Post Henry) N. Y	Magnetite	62.64		0.908		Richmond.
5	Chateaugay mine, Clinton county, N. Y	Magnetite	66.00		0.003		Richmond.
6	Chateaugay mine, Clinton county, N. Y	Magnetite	52.47	18.44	0.029	0.05	—
7	Andover mine, Sussex county, N. J	Magnetite	36.91	21.86	0.022	2.527	Blair.
8	Andover mine, Sussex county, N. J	Magnetite	62.31		0.001	0.059	Blair.
9	Hackelbarney mine, Morris county, N. J	Magnetite	48.38		0.057	0.529	Chauvenet.
10	Cornwall mine, Lebanon county, Pa	Magnetite	64.90	3.98	0.014	0.071	McCreath.
11	Cornwall mine, Lebanon county, Pa	Magnetite	57.05	8.65	0.007	2.581	McCreath.
12	Cornwall mine, Lebanon county, Pa	Magnetite	51.45	12.27	0.010	2.459	McCreath.
13	French creek, Chester county, Pa	Magnetite	56.13		0.040		Whitfield.
14	Hecla furnace, Lawrence county, Ohio	Siderite	33.29		0.144		King.
15	Monroe furnace, Jackson county, Ohio	Limonite	49.32		0.145		King.
16	Dover & Co., Amhurst county, Va	Specular and magnetite	48.47	21.58	0.103	0.352	Gorch.
17	Panic furnace, Smyth county, Va	Limonite	46.61	11.47	0.125	0.056	Gorch.
18	Cranberry, Mitchell county, N. C	Magnetite	32.37	29.99	0.010	0.128	Pitman.
19	Cranberry, Mitchell county, N. C	Magnetite	44.08		0.007	0.128	Pitman.
20	Penn. furnace, Greenup county, Ky	Limonite	54.39		0.167		King.
21	Shepherd bank, Lawrence county, Ky	Carbonate	40.61	14.87	0.126	0.227	King.
22	Taylor bank, Carter county, Tenn	Limonite	49.73	13.68	0.056	0.066	King.
23	Eureka mine, Jefferson county, Ala	Fossil ore	51.25	16.59	0.219	0.139	White.
24	Eureka mine, Tuscaloosa county, Ala	Limonite	46.59	15.07	0.179	0.318	White.
25	Shelby mine, Shelby county, Ala	Limonite	52.82	6.62	0.241	0.139	White.
26	Pilot Knob, Iron county, Mo	Specular ore	59.52	12.17	0.005	0.020	White.
27	Iron mountain, St. Francois county, Mo	Specular ore	64.67		0.019		King.
28	Iron mountain, St. Francois county, Mo	Specular ore	59.96		0.398		King.
29	Republic mine, Marquette county, Mich	Specular ore	67.02	3.38	0.024	0.037	Gooch.
30	Norway mine, Menominee county, Mich	Specular ore	60.20	12.43	0.047	0.048	Pitman.
31	Commonwealth mine, Marinette county, Wis	Specular ore	59.36	7.81	0.224		Gooch.
32	Black River Falls, Jackson county, Wis	Specular ore	37.09		0.047		King.
33	Iron mountain, Dodge county, Wis	Fossil ore	56.52		0.534		King.
34	Nipigon, Minn	Red specular ore	63.88	12.97	0.051	Trace.	—
35	Vermilion range, Minn	Red specular ore	67.17	4.61	0.083	0.020	—

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA — CONCLUDED.

No.	LOCALITY.	Kind of ore.	Iron	Silica	Phosphorus	Sulphur	Analyzed by —
36	Marion county, Texas	Limonite	47.55	8.92	0.139	0.070	Hevendon.
37	Cherokee county, Texas	Limonite	42.25	25.13	0.113	....	Magnenet.
38	Llano county, Texas	Magnetite	68.74	10.08	0.018	....	
39	Breece mine, Lake county, Col	Specular hematite	61.51	....	0.088	....	King.
40	Juragua, Cuba	Magnetite	61.94	7.18	0.027	0.382	Beth. Iron Co.
41	Juragua, Cuba	Magnetite	62.54	....	0.028	0.353	Booth, Garrett & Blair.
42	Signa, Cuba	Magnetite	58.10	15.50	0.034	0.046	Rattle & Nye.

THE IRON MINING POSSIBILITIES OF WASHINGTON.

Conditions Necessary for Profitable Iron Mining.

As already stated, the value of an iron ore deposit depends not alone upon the quantity and quality of the ore, but also upon its position as regards fuel, fluxes, transportation and markets, as well as facilities for mining.

Conditions in Skagit County.

In Skagit county along the south bank of the Skagit river, from Hamilton to Marble Mount, occur deposits of iron ore which are very favorably situated as far as fuel, fluxes and transportation are concerned. The Seattle & Northern Railroad is built as far as Hamilton and could easily be extended if it were necessary.

There are five different veins or ore bodies in this district, ranging in thickness from 6 to 50 feet, and dipping to the south and a little to the west at an angle of 55 degrees.

The conditions for mining in this district are very favorable, as a large body of the ore occurs high up the mountain some distance above the river, so that a tunnel could be put in from down near the river and a large body of the ore mined at a minimum expense.

Just above the iron ore occurs coal which is said to be of coking quality and in large quantities, but at present (1901) nothing is being done to develop these deposits. About 12 miles west of Hamilton, at Cokedale, deposits of good coking coal occur and the coke from here could be used in connection with the Hamilton ores should it be found on further investigation that the Hamilton coals are not coking coals.

Limestone suitable for fluxes are found in close proximity to the iron ores of this locality, and a few miles east of Hamilton large quantities of limestone occur.

Conditions in Kittitas County.

The iron deposits of Kittitas county are situated about twenty miles north and a little west of Clealum on the Clealum river, a tributary of the Yakima river, in the eastern spurs of the Cascade range. This district is reached by wagon road from Roslyn, the present terminus of a short branch of the Northern Pacific Railroad, up the valley and canyon of the Clealum river.

As given by the U. S. Geological Survey, Roslyn has an elevation of 2,273 feet above sea level, and the Clealum valley, where the iron ores occur, has an elevation of 2,800 to 3,000 feet above sea level. For about 17 miles of this distance from Roslyn, or to the Salmon Lasac river, the valley has an average grade of about 20 feet to the mile, but for the rest of the distance above there, to where the iron occurs, the grade is much steeper and the canyon narrower. On the west side of the valley, opposite the iron-ore deposits, the mountains rise very abruptly to an altitude of about 6,670 feet above the sea, or 3,670 to 3,870 feet above the valley; on the east the slope is much more gradual.

Conditions in King County.

In King county magnetite occurs in the Cascade mountains at a distance of about two and one-half or three miles north and a little west of Snoqualmie pass. These ores are about twenty-eight miles from North Bend, and about fourteen miles from Martin, a station on the main line of the Northern Pacific Railroad, on the east side of the summit of the Cascade mountains. The state wagon road from North Bend through Snoqualmie pass passes within about two and one-half miles of these deposits, and the Seattle & International Railroad has been located through this pass, but at present is built only as far as North Bend.

The ore in this district is not difficult of access, but it would have to be shipped by rail to some point where fuel is convenient, as there is no coal in that locality.

Conditions in Stevens County.

In Stevens county iron-ore deposits occur in two or three localities, which have been worked and the ore shipped to the Tacoma smelter and used as a flux, but they have not been used for the production of iron.

Twenty miles north and a little east of Colville, on the head waters of Clugston creek are a number of mines which have been located as iron properties, and considerable work has been done in developing one of these locations, and a wagon road has been built to the property.

Eleven miles west and a little south of Valley, a station on the Spokane Falls & Northern Railway, is situated another body of iron ore and some mining has been done here. This district is

reached by a trail, which leaves the United States Marble Company's wagon road about two miles from their quarry.

About two miles east of Valley are some more iron deposits, and these are very easy of access. These deposits were worked for several years on a small scale and the ore was brought by teams to Valley and shipped to Tacoma and used as a flux, but at present nothing is being done with these deposits.

The iron ores of Stevens county are all easy of access and the localities in which the iron occurs are well supplied with material for fluxes but lack fuel, hence the ore would probably have to be transported to some other locality in order to utilize it.

Conditions in Mason County.

About eleven miles northwest of Hoodsport, in Mason county, are deposits on which a number of locations have been made for iron. Hoodsport is a small town situated near the southern end of Hood's canal, and from this point to the iron deposits there is a good wagon road and a railway could easily be built if there was a demand for it. These deposits are about four miles above the upper end of Lake Cushman, on Boulder creek, about two hundred yards above where it empties into the Skokomish river. The country around Lake Cushman is very rough and mountainous. The mountain in which the iron ore occurs reaches an altitude of about five thousand feet above sea level and is quite steep. The ore in this district, if ever used, would have to be shipped to some other locality, as there is neither fuel nor fluxes to be found in connection with these deposits.

LAKE CUSHMAN DISTRICT.

ANALYSES OF IRON ORES FROM LAKE CUSHMAN, MASON COUNTY.

No.	Mine.	Iron.	Insoluble residue......	Phosphoric acid (P_2O_5)..	Alumina (Al_2O_3)......	Manganese (Mn_3O_4).....	Calcium ($CaCO_3$)	Analyst........
1...	....	16.34	24.20	.13	8.00	27.14	11.28	Fulmer.
2...	....	19.25	70.50	Trace	.65	.32	1.13	"
3...	....	4.13	19.04	.21	6.91	42.58	6.00	"
4...	....	10.66	27.39	.16	2.33	5.18	49.16	"
5...	....	10.20	11.64	.16	1.24	1.58	70.34	"
6...	....	13.76	29.35	.20	......	4.18	36.91	"

The above analyses were made from what are thought to be fair samples of the deposits being prospected in this locality for

iron. The analyses show that so far as iron is concerned the deposits have no value whatever. Number one and number three have considerable manganese and if they should be found in large quantities might be valuable on that account.

BLACK HILLS.

ANALYSES OF IRON ORES FROM THE BLACK HILLS, CHEHALIS COUNTY.

No.	Mine.	Iron.	Insoluble residue......	Phosphoric acid (P_2O_5)..	Alumina (Al_2O_3)......	Manganese (Mn_3O_4).....	Calcium ($CaCO_3$).....	Analyst........
8..	Float........................	52.81	18.04	Trace	1.06	.14	....	Fulmer.
9..	"	48.18	25.02	....	.02	.23	....	"
10..	Black sand..................	48.72	24.14	....	11.65	.18	....	"

The above analyses are from samples of float found in the Black hills and no ledges have been found as yet. Number eight has a fair per cent. of iron, but it also carries considerable titanium, and this would tend to injure it for the manufacture of iron. The samples were given me by parties in Olympia, and I know nothing about the conditions under which they were found. Numbers eight and nine looked as if they were nodules of consolidated black sand.

HAMILTON DISTRICT.

ANALYSES OF IRON ORES FROM THE HAMILTON DISTRICT, SKAGIT COUNTY.

No.	Mine.	Silica (SiO_2)...	Iron (Fe_2O_3)..	Alumina (Al_2O_3)......	Phosphorus (P_2O_5)......	Sulphur........	Iron...........	Manganese (Mn_3O_4).....	Calcium ($CaCO_3$).....	Analyst.
11..	Inaugural.........	19.98	62.70	3.30	.25	....	43.89	12.30	3.98	Thatcher.
12..	Hamilton	30.53	45.92	7.25	.72	.06	32.14	11.74	5.82	"
13..	Hamilton	20.24	52.46	7.40	Trace	....	36.72	13.04	9.77	"
14..	Inaugural.........	31.82	44.40	6.79	.41	Trace	31.08	14.28	5.83	"
15..	Hamilton	32.94	48.40	2.57	2.43	.16	33.88	7.31	8.81	"
16..	Inaugural	18.36	62.73	3.09	1.58	....	43.91	12.00	8.92	"
17..	Treadwell..........	22.85	62 46	3.17	1.00	....	43.72	8.08	3.78	"
18..	Pittsburg..........	28,05	47.03	8.43	.70	....	32.92	8.11	8.06	"
19..	Pittsburg..........	32.46	41 59	8.56	.45	....	29.11	13 11	6.71	"

THE LOCATION AND MODE OF OCCURRENCE OF THE ORE.

The iron ore deposits in the Hamilton district occur on the south side of the Skagit river at Hamilton, in the western spurs

of the Cascade range, about twenty-five miles above the mouth of the river. Deposits have been found as far up the river as Marble Mount, which is about twenty-five miles above Hamilton. The Hamilton deposits may be reached by the Seattle & Northern Railroad and are about fifty miles, by rail, from the tide water at Anacortes, or about twenty-five by boat by the way of the Skagit river. At Hamilton, where the iron deposits occur, the valley has an altitude, as given by the U. S. Geological Survey, of 94.56 feet above sea level, and at Marblemount, the point farthest up the river where the iron is known to occur, an elevation of 312.96 feet, making a grade for the valley from Hamilton to Marblemount of nine feet to the mile.

At Hamilton, the mountains on the south side of the valley rise abruptly from the river to an altitude above sea level of about 3,000 feet, while on the north side of the valley the ascent is more gradual. The country rock through this locality is sandstone, limestone, shales and slates. The iron ore occurs in the slates and lies parallel with the bedding.

Occurring in connection with the iron in this district, especially across the river from Hamilton, and lying above it are at least four seams of what is said to be a good grade of coal. Some work has been done on this coal, but for some reason it has been stopped and at present nothing is being done. The first vein is from 1,000 to 1,200 feet above the iron ore, and has a thickness of from 8 to 10 feet of coal with three streaks of boney matter from 1½ to 4 inches in thickness. Just below the coal is about 300 feet of sandstone, and then comes the slates in which the iron occurs. The second vein occurs about 100 feet above the first and has 6 feet of coal comparatively free from dirt. The formation between the two seams of coal is a gray sandstone with 4 feet of fire clay just below the upper vein of coal. From the second vein of coal to the third is 1,100 feet of gray sandstone. Number 3 is 3 feet thick and contains no dirt. Vein number 4 is 1,200 feet above 3, and the formation between the two is sandstone.

EXTENT OF IRON DEPOSITS.

Outcrops of iron-ore appear at intervals along the valley from Hamilton to Marblemount, a distance of about twenty-five miles. While the deposits have been found in a number or places along

IRON MOUNTAIN, NEAR HAMILTON.

INAUGURAL IRON MINE, NEAR HAMILTON.

the trend there has not been work enough done to tell definitely just what the relations of the different outcrops are to each other, but I am inclined to think they are lenses rather than veins and probably not continuous between the outcrops. The ore bodies vary in thickness from a few feet to 30 feet. From Hamilton to Birdsview, a distance of six miles, the iron ores appear at intervals on the south side of the Skagit river in five lines, one above the other, while at Marblemount only two lines of outcrops have been found so far. These outcrops trend approximately east and west and have a dip to the southwest of about 55 degrees.

CHARACTER AND COMPOSITION OF THE HAMILTON ORES.

The Hamilton ores are dark colored, massive appearing ores, having a medium specific gravity, for an iron ore, and when powdered some of them have somewhat of a reddish appearance, while others have a very dark, almost black appearance. The ores are all more or less magnetic. The reddish cast to the powder, however, shows that they contain some hematite. In places, as for instance in the tunnel on the Inaugural claim, the iron is found to be intimately mixed with a very white granular quartz, but most of the ore in the district seems to be free from this.

The following analysis, by R. W. Thatcher, shows the composition of the iron ore from the tunnel on the Inaugural mine, Hamilton district, Skagit county:

	Per cent.
Iron	43.89
Silica	19.98
Phosphorus	.11
Sulphur	....
Alumina (Al_2O_3)	3.30
Manganese (Mn_3O_4)	12.30
Calcium ($CaCO_3$)	3.98

A tunnel has been driven into the side of the mountain a distance of approximately 50 feet, to tap the iron ore on the Inaugural mine, and the sample from which the above analysis was made was taken from the face of that tunnel. In this tunnel, in places, the iron is intimately mixed with a very fine, white, granular quartz, such as was not found in any other place. The analysis shows the ore to be a little low in iron, somewhat high in silica, and quite a good per cent. of manganese, in fact enough to make a fair grade of spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine :

	Per cent.
Iron	32.14
Silica	30.58
Phosphorus	.72
Sulphur	.06
Alumina (Al_2O_3)	7.25
Manganese (Mn_3O_4)	11.74
Calcium ($CaCO_3$)	5.82

This is an average sample from this mine and is thought to show fairly well the character of the ore taken as a whole. The analysis shows the ore to be low in iron, very high in silica and phosphorus, with some alumina and quite a high per cent. of manganese. The ore, however, taken by itself, would not be a very valuable one from which to manufacture iron.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine, near the middle of the vein :

	Per cent.
Iron	36.72
Silica	20.24
Phosphorus	Trace
Sulphur	......
Alumina (Al_2O_3)	7.40
Manganese (Mn_3O_4)	13.04
Calcium ($CaCO_3$)	9.77

The ore in the Hamilton mine is of two grades, that in the central part of the ore body being a little better ore than that near the outer part. In the particular places where the openings have been made, there is about 18 inches of this better grade of ore. The above analysis shows the ore to be low in iron, high in silica and manganese, with considerable alumina and calcium. The amount of manganese in this ore would, perhaps, make it of value for producing spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the surface of the Inaugural mine. :

	Per cent.
Iron	31.08
Silica	31.82
Phosphorus	.18
Sulphur	....
Alumina (Al_2O_3)	6.79
Manganese (Mn_3O_4)	14.28
Calcium ($CaCO_3$)	5.82

The ore from which the above analysis was made came from the surface and shows the fact that the ore, in this particular deposit at least, has increased in iron with depth while it has de-

creased in silica, alumina, manganese, calcium and phosphorus. This sample is low in iron, high in silica, manganese and phosphorus. The per cent. of manganese is high enough to make a fair grade of spiegeleisen.

The following analysis by R. W. Thatcher shows the composition of the ore from near the wall of the Hamilton mine:

	Per cent.
Iron	33.88
Silica	32.94
Phosphorus	1.06
Sulphur	.16
Alumina (Al_2O_3)	2.57
Manganese (Mn_3O_4)	7.31
Calcium ($CaCO_3$)	3.31

The sample from which the above analysis was made is the poorer grade of ore from the Hamilton mine and, as the analysis shows, it contains less iron, manganese, alumina and calcium and more silica, phosphorus and sulphur. The per cents. of phosphorus, sulphur and silica are so high that they preclude its being classed as a Bessemer ore. It might, however, be used in connection with a better grade of iron ore, such as the Snoqualmie pass ore, and make a good pig iron.

The following analysis by R. W. Thatcher shows the composition of the ore from the shaft of the Inaugural mine:

	Per cent.
Iron	42.21
Silica	19.26
Phosphorus	.60
Sulphur	....
Alumina (Al_2O_3)	3.09
Manganese (Mn_3O_4)	12.00
Calcium ($CaCO_3$)	3.22

The sample from which the above analysis was made was taken from a shaft that has been sunk to the depth of 85 feet on this property, and shows the character of the ore at that depth. The ore is not very high in iron but contains a high per cent. of silica, phosphorus, and manganese. In some cases, however, ores having a lower per cent., even, of iron than this one has are used.

The following analysis by R. W. Thatcher shows the composition of the ore from the Treadwell mine.

	Per cent.
Iron	43.72
Silica	22.86
Phosphorus	.44
Sulphur	....
Alumina (Al_2O_3)	3.17
Manganese (Mn_3O_4)	3.06
Calcium ($CaCO_3$)	3.73

The Treadwell mine is located near Marblemount, which is twenty-five miles above Hamilton on the Skagit river, and the ore is about the same grade as that at Hamilton. This particular sample shows the per cent. of iron to be a little low, with a high per cent of silica, phosphorus and manganese.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	Per cent.
Iron	32.92
Silica	28.05
Phosphorus	.31
Sulphur	....
Alumina (Al_2O_3)	8.43
Manganese (Mn_3O_4)	8.11
Calcium ($CaCO_3$)	8.06

The sample from which the above analysis was made came from the ore body which is situated lowest down on the hill and shows the ore to be of a very poor quality, being low in iron, high in silica and phosphorus.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	Per cent.
Iron	29.11
Silica	32.46
Phosphorus	.20
Sulphur	....
Alumina (Al_2O_3)	8.56
Manganese (Mn_3O_4)	18.11
Calcium ($CaCO_3$)	6.71

There are two ledges or ore bodies on the Pittsburg mine and the sample from which the above analysis was made came from the upper one of the two. The analysis shows the ore to be low in iron and high in silica, phosphorus, alumina, and manganese. The only redeeming feature this ore has is its high per cent. of manganese and with the very high per cent. of silica it has, it is very doubtful if it will prove of very much value to use by itself, but might be used in connection with some good high grade ore, like the Snoqualmie pass ore.

The following analysis by E. Fulmer shows the composition of the ore from a new location by J. J. Conner.

	Per cent.
Iron	46.60
Insoluble residue	27.04
Phosphorus	.59
Sulphur	Not Det
Alumina (Al_2O_3)	None
Manganese (Mn_3O_4)	.19
Calcium ($CaCO_3$)	8.95

The above analysis shows the sample to have been above the average in iron and to be very similar to the ores of this district in other respects.

The following anlysis by S. Shedd shows the composition of the ore from the upper deposits or the one just below the coal:

	Per cent.
Iron	42.43
Silica	24.13
Phosphorus	.64
Sulphur	.25
Alumina (Al_2O_3)	9.54
Manganese (Mn_3O_4)	Not det.
Calcium ($CaCO_3$)	" "

The sample from which the above analysis was made was taken from the vein highest up above the river, and while no work has been done here the analysis shows the ore to be a little above the average in the amount of iron it contains, of the ores in the Hamilton district, and in other respects to be about the same as the average ore of this locality.

SNOQUALMIE PASS DISTRICT.

ANALYSES OF IRON ORES FROM SNOQUALMIE PASS, KING COUNTY.

No.	Mine.	Silica	Iron oxide	Aluminum oxide	Phosphoric acid	Sulphur	Iron	Phosphorus	Analyst.
20	Guye	3.60	95.45		Trace.		66.81	Trace.	Fulmer.
21	Guye	4.20	95.45				66.82		Fulmer.
35	Denny	5.78	89.22	5.84		.21	62.45		Shedd.
36	Denny	1.89	97.92	.28		.25	68.54		Shedd.

THE MODE OF OCCURRENCE OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie Pass district occur on the south fork of the Snoqualmie river near the summit of the Cascade mountains.

The pass, as determined by the United States Geological Survey, has an altitude above sea level of 3,131 feet, and Guye's peak 6,980 feet and Denny mountain 5,766 feet. The ores occur in Guye's peak and Denny mountain at an altitude of from 1,500 to 2,000 feet above the Snoqualmie river. The ore appears to occur in beds or isolated masses and not in veins. The country rock in this locality is marble, limestone, granite, and conglomerate and the iron ore occurs in connection with the limestone and marble more frequently than with the other kinds of rock. In

the tunnel on the Denny mine is found a coarse-grained white marble in which the particles are very loosely cemented together.

CHARACTER AND COMPOSITION OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie pass district are dark-colored heavy ores and vary from quite porous to very fine-grained masses. They have somewhat of a metallic luster, are strongly magnetic and when powdered give a black streak.

Below are given descriptions of the individual properties in Snoqualmie pass district.

THE F. M. GUYE PROPERTIES.—These properties are located on what is known as Guye's peak, about four miles northwest from Snoqualmie pass. Considerable development work has been done on these properties and some fine magnetic iron has been found here, but the question that has not been definitely settled as yet is the question of quantity. The ore here occurs in connection with marble and limestone principally.

The following analyses by Professor Elton Fulmer shows the composition of the ore from these properties:

	No. 1.	No. 2.
Iron	66.81	66.82
Silica	3.60	4.20
Phosphorus	Trace.	....
Sulphur	....	....

The analyses are of samples collected from two different localities and show the ore to be a very high grade ore almost free from phosphorus and sulphur, and as already stated, the only question that remains in connection with these deposits is the one of quantity.

THE DENNY PROPERTIES.—The Denny properties are located on what is known as Denny mountain, a high prominent peak about three and one-half miles south of Guye's peak, and about four miles southwest of Snoqualmie pass. A tunnel has been driven into the mountain for some considerable distance on these properties but nothing very encouraging has been developed. In the tunnel are exposed some very coarse-grained and poorly cemented limestones and white marbles.

The following analyses by S. Shedd show the composition of the ore from these properties:

	No. 1.	No. 2.
Iron	62.45	[illegible]
Silica	5.78	[illegible]
Phosphorus	....	....
Sulphur	[illegible]	.25

The analyses show the ore to be excellent in quality. It is uncommonly high in iron, low in silica and sulphur, with practically no phosphorus. Number one is from the surface about fifty yards from the tunnel. The question here again is quantity, and the indications are not very favorable for any very large body of ore.

CLEALUM DISTRICT.

ANALYSES OF IRON ORES FROM THE CLEALUM DISTRICT, KITTITAS COUNTY.

No.	Mine.	Silica........	Iron oxide........	Alumina and chromium oxide........	Phosphoric acid........	Sulphur........	Iron........	Phosphorus........	Manganese oxide........	Analyst.
22..	Emerson	15.58	67.28	1.92	....	....	47 10	....	....	Shedd.
23..	Hard Scrabble	14.00	68.38	6.02	....	....	47.87	....	Trace	"
24..	Iron Monarch .	7.50	66.05	25.95	Trace	Trace	46.24	Trace	....	"
25..	Roslyn.........	8.70	67.28	12.22	....	....	47.10	....	.25	"
26..	Yankee.........	7.84	73.83	5.67	....	....	51.68	....	.19	"
27..	Yankee.........	5.54	77.71	8.29	Trace	....	54.40	Trace	Trace	"
28..	Iron Monarch .	6.94	73.02	14.23	....	....	51.13	....	Little	"
29..	Roslyn.........	5.68	86.40	4.80	....	....	57.12	....	....	"

THE MODE OF OCCURRENCE OF THE CLEALUM ORE.

The ore in this district occurs in the contact between a sandstone and serpentine as shown by Smith and Willis, in their paper read before the Washington meeting, February, 1900, of the American Institute of Mining Engineers. The ore outcrops along the valley at intervals, from about one-fourth of a mile south of Boulder creek to Camp creek, a distance of one mile and a half.

To the east of these outcrops along the river, and from 700 to 1,600 feet above them, is another line of outcrops, known as the Emerson group of mines. These have been traced for about a mile. The ore bodies are lenticular and vary in thickness from a few feet to thirty feet.

The following as regards their geological position is taken from the paper by Smith and Willis, already referred to:

"They have a definite geologic position in the rock series of the district, and their distribution is determined by the geologic structure. They lie on the surface of an extensive formation of serpentine at and in the base of a sandstone called the Swauk sandstone. The serpentine is older than the sandstone. It had been much eroded when the sandstone was deposited, and the sandstone, although composed chiefly of granite sand, contains in its lower beds, near the serpentine, bits of decomposed

serpentine and heavy minerals derived from it. Limited lenses of shale composed of serpentine wash and also conglomerates of serpentine boulders occur at the base of the sandstone. Thus the surface on which the iron ores occur was an eroded surface, which, with the soil and other residual accumulations, was buried beneath granite sands. The relations and character of the ore indicate that it was a sedimentary deposit on the serpentine, was covered by the sands, and later metamorphosed to its present condition."

The nearest place to these iron deposits where coal has been found, in any quantity at least, is Roslyn, and these coals are not coking coals, so that it would seem that in order to smelt these ores it would be necessary to ship them some place to fuel or ship the coke to them, either of which would be expensive.

CHARACTER AND COMPOSITION OF THE CLEALUM ORES.

The ores of this district vary considerably in appearance and general characteristics and range from a high grade iron ore carrying 57 per cent. of metallic iron on the one hand to a serpentine on the other carrying less than 10 per cent. of iron. These ores may be separated into three classes, as follows: Massive, laminated and oolitic. The massive ore has a dull, greenish black color and when powdered gives a brownish black streak. The laminated ore varies in appearance, in some cases being dark red and in others having considerable of a metallic appearance, but in each case giving a deep red powder or streak when pulverized. The oolitic ore has a greenish black color and contains numerous oolites in an amorphous ground mass and when powdered gives a brownish black streak or powder. All of these ores are quite strongly magnetic and are apparently mixtures of hematite and magnetite. In some of the ore bodies all three classes of ore are found and in others only one class. The oolitic ore, so far as I could determine, is not found in the ore bodies farthest up on the hill, high above the river, but is quite common in those down near the river and especially those near Camp creek.

The samples from which the analyses given here were made are thought to be average samples of the ores in this district, having been selected with a great deal of care by the writer himself, and while samples could probably have been found that would have shown a higher per cent. of iron, it is thought that these samples show the average of the larger part of the ore in the district.

CLEALUM MOUNTAIN.

GUYE IRON MINE, NEAR SNOQUALMIE PASS.

GEOLOGY OF THE CLEALUM IRON DISTRICT.

The geology of this district has been very carefully worked out by George Otis Smith and Bailey Willis of the U. S. Geological Survey, and a summary of their results has been given in a paper read at the Washington meeting, February, 1900, of the American Institute of Mining Engineers, and published in Volume 30 of their Transactions, and from that paper is taken the most of what is given here as regards the geology of the district.

Smith and Willis divide the rocks of this district into two groups and designate them as those which are older, or pre-Eocene, and post-Eocene. These two groups are unconformable, and the iron ore occurs in the contact between the two formations.

"PRE-EOCENE ROCKS.—The oldest rocks of the area are slates, chert, limestone, quartz schist, and volcanic breccias and tuffs, constituting a pre-Eocene complex. All these rocks have been somewhat metamorphosed, yet rarely too such an extent as to prevent the determination of their origin. They were folded, sheared, and intruded by igneous rocks early in the history of the region, and have been more or less mineralized with cupriferous, and argentiferous deposits.

"One of the most voluminous of the intrusives in the pre-Eocene complex consisted of large masses of peridotite, now more or less altered to serpentine. These intrusive masses are scores of miles in length and several miles in width. They have in great part the form and relation of large dikes.

"The youngest of the pre-Eocene rocks is a granodiorite closely resembling that of the Sierra Nevada. The rock looks like an ordinary medium-grained granite, except that it is poorer in quartz and slightly darker in color. It constitutes the Mt. Stuart batholith, and that mass with others in the Cascades furnished the sands of the Swauk sandstone.

"EOCENE AND POST-EOCENE ROCKS.—Arkose sandstone constitutes the great mass of Eocene strata in the Cascade range. They are of wide-spread occurrence on the west as on the east of the range. In the Mount Stuart district, the Eocene sandstones are divided by an extensive flow of basalt, and occordingly the Eocene formations are: first, the lower sandstone, which is called the Swauk; second, the Teanaway basalt; and, third, the upper sandstone, which is called Roslyn.

"The two sandstones are very similar in general character, and the eruption of basalt which flowed from conduits now represented by innumerable dikes in the Swauk sandstone, appears to have occupied a brief interval, after which the conditions of erosion and deposition were essentially the same as before it.

"The economically important facts of these Eocene rocks are the

occurrence of a good grade of steam coal mined at Roslyn, and the possibly valuable iron ores at the base of the Swauk.

"The post-Eocene formations are of both sedimentary and volcanic origin. Basalt flows, younger than the Teanaway basalt, connect with basalts which form the great expanse of the Columbia plain far to the east. A complex mass of more acid volcanic rocks, chiefly andesite, occurs in intricate relations with other formations about the head waters of the Yakima river, and overlying the Swauk sandstone west of the head waters of the Clealum river, forms the summit of Goat mountain."

The following analysis by S. Shedd shows the composition of the ore from the Emerson mine.

	Per cent.
Iron	47.10
Silica	15.58
Phosphorus	....
Sulphur	....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	1.92

The analysis shows the ore from this mine to carry a fair per cent. of iron, a rather high per cent. of silica, a small amount of alumina and chromium, and no phosphorus or sulphur, and is a fairly good iron ore.

The ore body in this mine is about 30 feet wide and the walls are serpentine. The ore is of a laminated character, and different parts of the ore body would vary considerably in the amount of iron contained, but it is believed the sample analyzed would represent fairly well the average of the whole body of ore in this mine so far as the present exposures are concerned.

The following analysis by S. Shedd shows the composition of the ore from the Hard Scrabble mine.

	Per cent.
Iron	47.87
Silica	14.00
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	6.02
Manganese	A little

The analysis shows the ore from this property to be very similar to the Emerson, which it joins.

These properties are situated on Magnetic point at an altitude of about 1,500 to 2,000 feet above the Clealum river at Camp creek. Some work has been done on these properties and the ore bodies uncovered for some distance. The occurrence of the ore in this property is also similar to the occurrence of the ore in the Emerson.

The following analysis by S. Shedd shows the composition of the ore from the Roslyn mine:

	Per cent.
Iron	47.10
Silica	8.70
Phosphorus	....
Sulphur	....
Alumina and Chromium (Al_2O_3 and Cr_2O_3)	12.22
Manganese	.25

The analysis shows the ore to be a little low in iron, free from phosphorus and sulphur and quite high in aluminum, but at the same time it is a fair grade of ore. The ore in this mine occurs under conditions similar to those under which the ore in the Iron Monarch, wh'ch it joins, occurs. The ore body is about ten feet wide and is about half of it oolitic ore and the other half laminated ore. The sample analyzed was an average of the laminated ore, and is seen to be very similar to the oolitic ore, with the exception that it does not contain more than half as much aluminum.

The following analysis by S. Shedd shows the composition of the laminated ore from the Yankee mine.

	Per cent.
Iron	51.68
Silica	7.84
Phosphorus	....
Sulphur	....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	5.67
Manganese	.19

The analysis shows this to be a good iron ore. While it is true the per cent. of iron is not as high as it is in some iron ores, still it is above the average and then it is free from phosphorus and sulphur and does not contain a high per cent. of silica or aluminum. In this mine the oolitic ore does not occur but the laminated and massive ores do occur, and the sample was an average sample of the laminated ore. Some work has been done on this property and the samples taken were from the breast in the tunnel. The ore body in this mine is about fifteen feet wide and the laminated and massive ores are about equally divided.

The following analysis by S. Shedd shows the composition of the ore from the Iron Monarch mine.

	Per cent.
Iron	46.24
Silica	7.50
Phosphorus	Trace
Sulphur	Trace
Alumina and chromium (Al_2O_3 and Cr_2O_3)	25.96
Manganese	....

The analysis shows this sample to be a little low in iron and to contain a very high per cent. of aluminum. While the aluminum and chromium were not separated, and the per cent. of each determined, the amount of chromium is not large and will probably not exceed 5 per cent. at the outside, so that there is probably 21 per cent. at least of alumina. The sample from which the above analysis was made is what has been described elsewhere as oolitic ore of a greenish black color and made up of round grains the size of mustard seed up to as large as a pea. These grains are embedded in an amorphous or finely-crystalline ground mass. The ore body in this mine is about ten feet wide and is about half of it this oolitic ore.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Yankee mine:

	Per cent.
Iron	54.40
Silica	5.54
Phosphorus	Trace
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	8.29
Manganese	Trace

The analysis shows the massive ore from this mine to carry a higher per cent. of iron than the laminated ore; it also has a higher per cent. of aluminum than the other, but not enough to interfere seriously with its smelting qualities.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Iron Monarch mine:

	Per cent.
Iron	51.13
Silica	6.94
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	14.23
Manganese	.37

The above analysis shows the massive ore from this mine to be higher in iron and lower in alumina than the oolitic ore from the same mine.

The following analysis, by S. Shedd, shows the composition of the highest grade massive ore found in the Clealum district:

	Per cent.
Iron	57.12
Silica	3.68
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	4.80

The above analysis shows this to be a good grade of iron ore.

The following notes and analyses are from a manuscript report on the Clealum iron ores by R. H. Stretch, E. M.:

"The following is a report on eighteen sacks of ore taken at regular distances across the body with a view to get a fair sample of the quality at that point. The analyses were made by Professor Chas. F. Chandler and C. E. Pellew of Columbia college, New York.

Silica	10.28	Titanic acid	None
Iron	55.06	Sulphur	None
Alumina	.60	Carbonic acid	None
Lime	.53	Loss on ignition	5.30
Magnesia	1.48	Oxygen, alkalies, etc	26.6061
Manganese	.11		
Phosphorus	.0139		100.0000

"Another analysis of the ore tested at the Lanarkshire Steel Works, Motherwell, England, gave as follows:

Silica	5.41	Alkali	2.49
Ferric oxide	57.44	Carbonic acid	1.90
Ferrous oxide	15.58	Phosphoric acid	.161
Aluminum oxide	5.31	Sulphuric acid	Trace
Manganous oxide	1 65	Combined water	3.13
Oxide of nickel	2.98		
Oxide of cobalt	Trace		98.87
Chromium sesquioxide	2.12	Iron	53.82
Lime	Trace	Phosphorus	.025
Magnesia	.30		

"The table following gives the results obtained by Dr. Edward Riley, of London, England, whose standing as a consulting metallurgist and analyst can scarcely be said to be second to that of any expert in Europe, and who is almost as well known in the United States as in his own country:

No.	Iron	Sulphur	Phosphorus	Chromium	Oxides of Ni. and Co.	Silica	Alumina	Magnesia	Lime	Oxide of Mn.
1...	49.55	Trace	Trace	2.04	1.20	7.65	9.16	3.87	Trace	1.00
2...	55.35	0.07	0.08	1.99	0.92	7.55	3.66	2.16	1.17	2.20
3...	51.66	0.05	0.02	2.06	0.90	5.85	8.30	3.26	None	0.65
4...	50.76	0.04	0.013	2.65	0.70	5.90	11.90	1.00	1.15	0.69
5...	52.26	0.04	0.016	3.18	1.10	6.10	5.40	2.75	1.25	1.15
Av.	51.916	0.04	0.0258	2.381	0.964	6.61	7.684	2.608	0.714	1.138

GENESIS OF THE ORES.

Willis and Smith, in their paper already referred to, give the following hypothesis as regards the Clealum ores:

"SOURCE OF THE IRON.—The iron concentrated in the hematite and magnetite of the ore may be of extraneous origin or derived from an adjacent rock. In the facts of its position and association, there is no evidence to show that it is a deposit brought in from any more or

less remote extraneous source. There is much, on the contrary, to connect it with the serpentine. In its field relations, the ore lies on the serpentine, contains serpentine waste, and grades into shale derived from serpentine. The analysis of the ore and serpentine show that they both contain, in addition to the usual rock constituents, such occasional ones as chromium and nickel. Magnesia, an important constituent of serpentine, is also found in the ore. It is, therefore, reasonable to suppose that the iron ore is a result of concentration from the serpentine.

"CONDITIONS OF DEPOSITION.—The iron ore occurs on a surface of unconformity, the surface of the serpentine formerly exposed to the weather, and later buried under sands of the Swauk formation. In order to form a hypothesis of the conditions of concentration, it is necessary to interpret the facts of the unconformity.

"The basal-beds of the Swauk formation, other than the relatively limited occurrence of iron ore, are generally coarse arkose and more locally conglomerates, which consists of granite, greenstone and slate pebbles mixed, or of serpentine boulders alone, or rarely of granite boulders alone. The conglomates are exceedingly local in extent, and when composed almost wholly of surpentine or granite are restricted to areas of those rocks underlying. The serpentine conglomerates contain only occasionally a granite pebble or one of any other rock than serpentine. The granite conglomerates contain a larger, but yet surprisingly small proportion of slate or quartz pebbles.

"These facts, taken in connection with the enormous volume of arkose which constitutes the Swauk and Roslyn formations, indicate that the conditions limited the transportation of boulders and shingle, but favored the accumulation of granite sands, and, furthermore that the localities where serpentine was weathering were for a time protected from the widespreading deposits of arkose.

"The basal contact of the Swauk with the older formations is exceedingly uneven, and when traced out reveals the bold relief of the Eocene topographic surface, in which the soft shattered serpentine corresponded with lowlands. These depressions, which received little or no wash of other rocks than serpentine, may have been watersheds limited to areas of that rock. Here meteoric waters leached out the soluble parts of the disintegrated rock, and the mantle of residual material was deep. The climate was sub-tropic and vegetation abundant.

"As the coast of the rising water-body of the early Eocene time was established it assumed a very irregular outline, with numerous bays and promontories. The climate became favorable to very rapid disintegration of the granite, probably through slight hydration of the feldspar, without marked chemical change. At certain points along the coast, streams delivered the granite waste, which was built into beaches, spits and bars by shore currents. Behind the beaches and spits, lagoons were enclosed and, in some instances, such lagoons corresponded to shallow bays which received the drainage from areas of serpentine. That drainage was charged with iron and with decaying plants. The conditions were thus favorable for precipitation of iron either as ferrous carbonate or as

a hydrate of the sesqui-oxide in the shallow water of the lagoon. As the shore line of the slowly rising water-body advanced upon the land, the several conditions advanced with it, and in favorable localities a deposit of iron was a characteristic, and more or less extensive, basal deposit of the sediments. The conditions are believed to have been closely analogous to those which accompanied the deposition of the carbonate ores that have been dug in the Cretaceous formations about Baltimore, Md.

"CHEMICAL RELATIONS.—In connection with the hypothesis that the ore is the product of decay of the serpentine, a comparison of the analyses of the two is essential. The serpentine, of which the following is an analysis, was collected at some distance from the Clealum river locality, but fairly represents the rock at that point. It is here compared with the average sample of ore taken by Mr. Willis.

	Serpentine, Per cent.	*Ore, Per cent.*
SiO_2	39.	7.5
TiO_2	Trace.	.7
Al_2O_3	1.75	21.9
Cr_2O_3	.47	2.2
Fe_2O_3	5.16	37.1
FeO	1.71	21.3
MnO	.15	Trace.
MgO	38.	2.3
H_2O	13.74	6.8
$K_2O—No_2O$	.10	Undet.
P_2O_5	Trace.	.09
NiO	.10	.2
S	.03	.03
CO_2	None.	.15
	100.21	100.27

"In comparing these two analyses we may consider the lean ore as a rearranged, but chemically little modified, residual product of the serpentine. In such comparisons most students of the subject of weathering have regarded alumina as the constituent least liable to removal, and therefore best adapted to serve as a basis of calculation.

"Supposing none of the alumina to have been lost in the course of the weathering of the serpentine, the alumina present in the residual product furnishes a measure of the amount of concentration involved in the process, and also of the amount of the material removed. In the present case, the alumina percentage having increased from less than two to nearly twenty-two, it would follow that twelve and one-half units by weight of the serpentine were required to furnish one unit of the residual deposit. Calculating the losses for the principal constituents it is found that the material removed has been in the main silica, magnesia and water. The approximate losses suffered by these constituents expressed in percentages are 96, 99 and 97 per cent., respectively. There is no apparent loss of ferrous iron, but in view of the probable interchanges of the two oxides of iron, the result may, perhaps, be expressed in terms of the iron itself, which shows a loss of 31 per cent. in the course of the decomposition of the serpentine into the residual

product. There were also small losses of manganese, chromium, phosphorus, nickel and the alkalies, many of these losses being large if expressed in terms of the amount present in the serpentine."

The amount of concentration as here shown by Willis and Smith may seem very large and almost unreasonable but there are cases on record* where serpentine weathered into a residual soil and, based on the amount of alumina, showed a concentration of nearly thirty to one. The two cases are quite similar but differ in the fact that in the soil the amount of silica is sufficient to combine with the alumina while in the iron ore there is more than enough alumina to combine with the silica and the alumina must therefore be present in the free or uncombined condition.

From the foregoing it is plain to see that Willis and Smith attribute the Clealum iron ores to the weathering and concentration of the serpentine in which they are found at present and that they are not contemporaneous with them.

COLVILLE AND VALLEY DISTRICT.

ANALYSES OF IRON ORES FROM STEVENS COUNTY.

No.	Mine.	Silica	Iron Oxide	Aluminum and Chromium Oxides	Phosphorus Acid	Sulphur	Iron	Phosphorus	Analyst.
37..	Silver King, Valley	1.66	96.51	....	....	.38	67.56	....	Shedd.
38..	Silver King, Valley	1.12	97.28	....	....	.25	68.10	....	"
39:	I. X. L., Colville	4.49	80.08	2.00	.72	.32	56.58	.31	"
40..	I. X. L., Colville	14.90	72.12	2.48	.68	.32	50.48	.30	"
41..	Capital, Valley	5.80	84.55	1.85	.36	.33	59.19	.16	"
42..	Vigilant, Valley	3 54	83.62	3.18	.51	.21	58.53	.22	"

THE MODE OF OCCURRENCE OF THE ORES.

The general character of the region in which the iron ores of Stevens county occur, is that of a mountainous country with comparatively level valleys of considerable extent along the larger streams and the mountains rising gradually until an altitude of from 2,000 to 3,000 feet above the valleys is reached. The rocks of this region are limestones, shales, slates, serpentines, porphyries and marbles. The ores occur both in veins and in bedded deposits principally in the limestone and porphyry.

*Merrill: Rock, Rock-Weathering and Soil, p. 226.

CHARACTER AND COMPOSITION OF THE STEVENS COUNTY ORES.

The ores of Stevens county are principally hematites and limonites, and vary in appearance and texture from a very compact metallic-appearing mass to a finely divided loose red powder which has been used very successfully as a paint. Some of these ores again have small octahedral crystals of magnetite scattered profusely throughout the mass.

The ore from the Clugston creek district is a limonite or bog ore of a porous nature and ranges in hardness from a soft decomposed ore to a hard flinty ore. When pulverized it gives a brown streak and powder. The ores east of Valley are limonites having a deep red to almost black color, and when pulverized vary in color from a brown to dark red, indicating that in some cases at least there is some hematite present. The ores from west of Valley are hematites with some magnetite and vary in appearance from deep red to metallic. These ores when pulverized give a deep red streak and powder. The ores of Stevens county carry a high per cent. of iron, running from 50 per cent. to as high as 68 per cent. metallic iron.

THE CLUGSTON CREEK DISTRICT. — This district is about twenty miles north and a little west of Colville, T. 39 N., R. 37 E., section 11. The country rock in this district is a limestone and the iron ore seems to occur in masses, and not in a continuous vein, in the limestone and varies from well concentrated iron ore to limestone with very little iron ore in it. Two tunnels have been run on one of these properties, and at the end of the lower tunnel a shaft sixty feet deep has been sunk, so that a depth of 100 to 120 feet has been reached on this property. In the upper tunnel considerable ore was found, but in the lower one and in the shaft no ore was found. The ore in this district from present indications, so far as I was able to judge, is of very limited extent.

The following analyses by S. Shedd show the composition of the ore from the I. X. L. mine:

	Per cent.	*Per cent.*
Iron	56.58	50.48
Silica	4.49	14.90
Alumina	2.00	2.48
Sulphur	.82	.82
Phosphorus	.31	.30

The analyses show the ore to carry a good per cent. of iron and not an unusually high amount of sulphur or phosphorus and

to vary considerably in the amount of silica. The amount of phosphorus is too high for a Bessemer ore.

The following analyses by S. Shedd show the composition of the iron ore from the Silver King mine:

	Per cent.	Per cent.
Iron	67.56	68.10
Silica	1.66	1.12
Alumina	....	....
Sulphur	.38	.25
Phosphorus	....	....

The analyses show this ore to be a very fine high grade iron ore. The samples analyzed were both from the same property. Some development work has been done on this property, a tunnel having been run in on the ledge for about forty feet, but as the hill has a comparatively gentle slope no very great depth has been reached. The country rock is shale, slate, limestone, and serpentine. The question of quantity is one that remains to be determined, as with the amount of work done it is not possible to tell very much as to the extent of the ore body.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Capital mine:

	Per cent.
Iron	59.19
Silica	5.80
Alumina	1.85
Sulphur	.33
Phosphorus	.36

The above analysis shows the ore to be a good grade iron ore, a little high in sulphur and phosphorus for a Bessemer ore, however. This property is situated about two miles east of Valley, a small town on the Spokane Falls & Northern Railroad. The ore appears to occur in a bedded deposit and varies from a soft, loose, reddish mass to a hard compact ore, occurring in more or less concretionary or nodular masses. Considerable ore has been shipped from here to the Tacoma smelter and used as a flux in the smelting of other ores.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Vigilant mine:

	Per cent.
Iron	58.58
Silica	3.54
Alumina	3.18
Sulphur	.21
Phosphorus	.51

The analysis shows this sample to be a good ore as far as the per cent. of iron it contains is concerned, but, like the preced-

ing one, to be too high in sulphur and phosphorus for a Bessemer ore. The occurrence of the ore in this mine is similar to that in the Capital. The sample analyzed was a finely divided, loose, uncompacted mass, and similar to the ores from this locality that have been used to a limited extent as a roof paint.

CONCLUSIONS.

Several things must be taken into consideration in determining the location of iron and steel industries or plants, the most important of which are the following: iron ore, fuel, fluxes, price of labor, and nearness to markets.

The preceding analyses show that Washington has some very high grade iron ores, but the question that has not been settled as yet is the one of quantity. In most of the districts of the state where iron is found so little work has been done that it is not possible to say positively whether the ore occurs in large quantities or not, and since the quality of the ore is good it would seem to be worth while to spend money enough in prospecting thoroughly some of the best districts to determine the extent of the deposits.

The Snoqualmie pass, the Clealum, and the Stevens county deposits are all situated long distances inland, and in most cases some distance from railroads. The Snoqualmie pass district, which contains the highest grade of iron ore, is about fifty miles from tide water and the Clealum district is about eighty miles, and no fuels near them except wood for charcoal. This would probably mean the paying of freight on them to tide water some place on the Sound, and unless the freight rate could be lowered very materially from what it is at the present time it would tend to prevent the using of these ores.

The question of good fuel is a very important one in the manufacture of iron and one that, so far as I can learn, has not been fully solved as yet in Washington. Charcoal makes a very high grade pig iron, but it is expensive and especially so where it has to be made from soft wood as it does here. Washington has large deposits of coal, some of which are coking coals, but the coke is not of the best quality, however, for the manufacture of iron. A good coke for iron furnaces should be low in ash, free from phosphorus and sulphur, and hard enough so as not to crush when charged into the furnaces. If it is high in ash it takes just that much more flux, as it has to be gotten rid of by this

means. As already stated, a very small per cent. of phosphorus or sulphur in a pig iron injures it for many purposes. If the fuel contains these substances they show in the pig iron the same as though they had been in the ore.

While analyses of the Washington cokes have not been made in connection with this report, the best data obtainable seems to indicate that they are high in ash and contain some phosphorus and sulphur. They are also soft cokes as compared with the best grades of coke for iron furnace work.

Washington has plenty of material suitable for fluxes and no fear need be felt in this particular. Labor is perhaps a little higher in Washington than it is in the East, but the difference would have very little effect on the price of iron. The whole Pacific Coast would furnish the market, as very little pig iron, if any, is being produced in any of the states west of the Rockies, except Washington, at the present time (March, 1902), and the steel and iron being used on the Coast is shipped from the East.

The results shown here are rather against the probability of Washington ever becoming a very large producer of pig iron from ores occurring within her own borders, at least, unless other deposits than those known at present are found. There is, however, one factor that has not been taken into consideration as yet, and that is the British ore occurring on Texada island and perhaps some of the other islands in the Straits of Georgia.

Number 7, in the table of analyses of Washington iron ores, shows the ore to be of very high grade, carrying 67.91 per cent. of iron, 2.96 per cent. of silica, 1.05 per cent. of calcium carbonate, and practically free from phosphorus and sulphur. This Texada ore is a heavy, black magnetite, and is said to occur in large quantities and is easy of access. The ore could be mined and loaded on boats or scows and transported to any place on the Sound at very small cost per ton.

If, on further investigation, it should be found that the Washington coke is suitable for use in the manufacture of iron, it is possible, perhaps, that by using the Texada ore alone, or by mixing it with the ores found in this state, that a considerable iron industry might be built up at some place on the Sound.

A MAP OF THE KNOWN COAL FIELDS OF WASHINGTON.

THE COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES.

INTRODUCTION.

The first authentic record we have of coal being found in Washington was in 1851, when some pieces of coal were picked up on the Stilaguamish river. Samples were sent to Washington, D. C., to be analyzed, and were found to be of good quality. Later investigations made by Rev. G. F. Whitworth showed however that the seams were too thin to be profitably worked.*

On Bellingham bay the first discovery of coal was made in the fall of 1852. Some work was done on the outcrop and about 150 tons were shipped, but by that time it was discovered that the coal was of poor quality and not in sufficient quantity to be of value, and it was therefore abandoned.

The next year, that is, in the fall of 1853, two men, Brown and Hewitt, discovered coal at Sehome. They were logging for the mill on Whatcom creek and found the coal where it had been uncovered by the uprooting of a large fir tree. They sent some of the coal to San Francisco for trial and a short time afterward received an offer of twenty thousand dollars for their claim, which they promptly accepted. For a number of years this was the only mine in the territory that was operated to any extent. It was finally abandoned a number of years ago.

In 1853 Dr. M. Bigelow found coal on Black river near Seattle. The vein was opened up and operated until the time of the Indian outbreak in 1855. Two of Bigelow's partners, Fanjoy and Eaton, were killed by the Indians and the mine was abandoned. Several attempts have since been made to re-open the mine but the coal contains too much dirt to make it profitable.

Early in the fifties coal was discovered on the Skookumchuck in the vicinity of the present town of Bucoda. The territorial

*Coal Mines of Western Washington, Rev. G. F. Whitworth. Resources of Oregon and Washington, Portland, Oregon, December, 1881.

penitentiary was located at this place and the convicts were employed for a number of years in the coal mine. When the penitentiary was removed to Walla Walla the mine was closed down.

Coal was also found on Clallam bay and was opened up in 1864 or 1865. The coal was of good quality but the vein was too thin to be profitably mined and so nothing has been done with it for many years.

In 1863 two very important discoveries of coal were made. The first was at Issaquah or Gilman, and the other a month or two later on Coal creek near Lake Washington, about where the town of Newcastle now stands. A number of Seattle men, including Daniel Bagley, G. F. Whitworth, John Ross and other well known pioneers acquired an interest in the property and began active development. The coal was first carried to Lake Washington in wagons, transported across the lake by barges, and then carried to Seattle in wagons. In 1867 the Lake Washington Coal Company, consisting of the above named gentlemen and others, was incorporated for the purpose of carrying on more extensive developments. A new opening was made and the transportation facilities improved. The coal was carried down Black river to the Duwamish, thence down the Duwamish to Elliott bay. Barges were first employed and afterwards steamers.

In 1870 the property was sold to the Seattle Coal Company. The new company immediately began to construct a tramway to Lake Washington from the mine and another from Lake Washington to Lake Union over the portage. A little locomotive and train of cars brought the coal from the mine at Newcastle down to Lake Washington, where the whole train was loaded on a barge and carried over to Union bay were it disembarked onto the portage tramway. After passing over the portage the train was loaded on another barge on Lake Union and taken to the point where the Western mill now stands. From there the train proceeded up town to the coal bunkers, which were situated somewhere on Pike street.

Early in the seventies Seattle was making determined efforts to secure railroad communication with the outside world. The Northern Pacific Railroad Company decided on Tacoma as its western terminus and showed a disposition to leave out Seattle

altogether. The citizens of Seattle therefore organized the Seattle & Walla Walla Railroad and Transportation Company and began a line of their own. They constructed the road to Renton and Newcastle and from that time forward the old portage route was abandoned.

Coal was discovered near Renton in 1873 by Mr. E. M. Smithers. Together with T. B. Morris, C. B. Shattuck and others he organized the Renton Coal Company for the purpose of developing the property. The coal was run down on tram cars from the mine opening to the Duwamish river where it was loaded on barges and towed into Seattle.

The Talbot mine was opened near the Renton Coal Company's property in 1874. John Leary, John Collins and J. F. McNaught, who had control of the property, organized the Talbot Coal Company. After a few years of operation they found their vein badly faulted and finally abandoned it.

Somewhere about 1862 or 1863 a gentleman named Mr. Van Ogle discovered coal in the canyon of Carbon river. He found it in such large quantities and over such a wide extent of territory that he concluded that a single claim would be of no particular value to him, so he did not interest himself any further in the matter. During 1874 and 1875 a large number of coal claims were taken and considerable prospecting done. In 1876 the Northern Pacific Railway built a line to Wilkeson and afterward to Carbon Hill. The original Wilkeson mine was abandoned after about three years operation.

The Green river coal field was discovered at a later date. Since that time new discoveries have been made in a great many different places, so that the limits of the known coal bearing rocks are being gradually extended.

GEOLOGY OF THE COAL MEASURES.

For the most part the coal seams of Washington occur interbedded in a series of light-colored sandstones and shales, with sandstones as the predominating rocks. The latter are usually bluish or grayish in color, but often weather into light buff owing to the oxidation of the iron carbonate which they contain. These rocks are not confined to the districts where workable coal seams are known to occur, but outcrop at intervals over the principal part of western Washington. In some places the strata are found

almost horizontal, but usually they are considerably folded and faulted and the upturned edges deeply eroded. Careful measurements of the series in the neighborhood of Puget sound, made by Mr. Bailey Willis, has shown a thickness of about ten thousand feet.

Carbonaceous matter is distributed in greater or less quantity throughout the rocks of the whole series. Small streaks of coal are found in most of the sandstones. The shales vary in color from light gray to black, according to the amount of carbonaceous matter present. All gradations are found between carbonaceous shale and pure coal. While the number of workable coal veins is small, being perhaps not more than ten or fifteen in any one district, the number of seams of more or less impure coal is very large, considerably over a hundred being known. All the veins thus far discovered which are clean enough and with the coal in sufficient quantity to be of commercial value are contained in the lower-most three thousand feet of the series. The upper two-thirds have thus far proven barren of workable seams, although rich in disseminated carbon. From the evidence of fossil leaves collected from various localities Professor F. H. Knowlton has determined these rocks to be of the Eocene age.

At the time these sediments were laid down the region between the present Cascade and Olympic mountains was a shallow sea or wide lagoon, more or less completely cut off from the ocean. That it was fresh or brackish water is shown by the character of the animal remains embedded in the sediments.* These are mostly unios or other fresh water forms.

During the whole of the long period in which these sediments were being deposited the region was undergoing a gradual but persistent sinking. The evidence of the coal seams in the lowest strata clearly shows that at that period the water at intervals was very shallow, and at the end of the period after sediments nearly two miles deep had been deposited the water still remained at about the same depth, showing that in the meantime the bottom of the sea had sunk two miles. These nicely adjusted forces of nature permitted the accumulation of a practically unbroken series of sediments throughout the whole period.

Subsidence did not take place at a uniform rate. There

*Invertebrate Fossils from Pacific Coast, C. A. White, Bulletin 51, United States Geological Survey, p. 56.

were periods during which the process of sedimentation shoaled the waters faster than the sea floor sank, and this continued until the water was shallow enough to support a swamp vegetation, which thereupon spread over the broad lagoons and flourished with great luxuriance. In regard to the climate, Professor F. H. Knowlton * says: "The lower beds, on account of the abundance of ferns, gigantic palms, figs, and a number of genera now found in the West Indies and tropical South America, may be supposed to have enjoyed a much warmer, possibly a subtropical temperature, while the presence of sumacs, chestnuts, birches and sycamores in the upper beds, would seem to indicate an approach to the conditions prevailing at the present day."

Alternating with the periods of coal formation, there were long lapses of time during which the water was too deep to admit of swamp growth. These were the times when subsidence proceeded at a more rapid rate than sedimentation, or at least kept pace with it. Sand and clay were then deposited. The final results of this intermittant, long continued subsidence was that we now have a large number of coal seams and layers of more or less carbonaceous matter interstratified with beds of sandstone and shale.

In order to maintain the water in a fresh or brackish condition either the outlet to the sea was very narrow or the climate must have been even more humid than it is at present. When we consider that notwithstanding the great volumes of fresh water being continually poured into Puget sound the water is not appreciably freshened it is difficult to account for the prevalence of fresh water forms in the Eocene sea except on the hypothesis that it was almost entirely cut off from communication with the open sea. The Olympic and Cascade mountains had not then risen to their present height but were probably rather in the form of low hills. The rocks of which they were formed were mostly of granitic type, as shown by the character of the sediments derived from them. The coal bearing rocks are known to occur along the western slope of the Cascade mountains from the northern border of the state southward to the Columbia river. It is probable that rocks of the same age form a rim around the foothills of the Olympics. Coal has been found in a number of places in

* Geological Atlas of the U. S., Tacoma Folio, U. S. Geol. Survey.

that part of the state, but owing to the very heavy forests and almost entire absence of roads very little is known about the region. Intermediate between the eastern and western parts of the field there was probably a nearer approach to marine conditions. Marine fossils found in Duwamish valley indicate that the border of estuarine conditions was somewhere between that locality and the coalfields to the eastward. The greater part of these fossils are identical with species found in the Tejon group of California, which is of Eocene age.*

VARIETIES AND USES OF THE COAL.

The coal is essentially a lignite in character. In certain limited localities, however, where great internal disturbance has taken place so that the coal has been crushed and rolled it has lost much of its volatile constituents and has become bituminous. The lignite is usually quite hard and breaks into more or less cubical forms. The bituminous coals are rather soft. They have been rolled out between their walls and thoroughly crushed, so that a considerable percentage of the volatile constituents have escaped and the coal is consequently richer in fixed carbon. The semi-bituminous or steaming coal lies midway between these two. Frequently the change from lignite to bituminous and back again occurs within the same vein.

The value of the coal depends upon the varying percentages of moisture, ash, sulphur, volatile hydro-carbons, and fixed carbon. In regard to the first three of these the smaller the percentage the greater will be the value of the coal. The ash is derived from two sources: 1st, the natural ash present in the plant from which the coal is derived; 2d, the dirt carried into the original coal swamp by streams and deposited with the coal. This latter source is usually by far the most important one. In a large number of coal seams it is the high percentage of ash rather than any other drawback which prevents the coal from being placed on the market. A number of representative analyses of coal from the principal mines show a range in the percentage of ash from 5.76 to 12.55. The samples from which these analyses were made were presumably taken so as to represent a fair average of the commercial article as it was placed on the market.

* Correlation Papers, Eocene, W. B. Clark, Bulletin 83, U. S. Geol. Survey, p. 108.

A high percentage of moisture detracts from the heating qualities of the coal because all the moisture has to be volatilized before any of the heat energy is available for any other purpose. The lignites of course contain more moisture than the bituminous coal and consequently have not such high heating qualities.

A certain percentage of volatile hydro-carbons is essential to coal. For steam generating purposes the semi-bituminous has been found to be the best. It has a representative analysis as follows: moisture, less than 5 per cent.; ash, 5 to 10 per cent.; volatile hydro-carbons, 30 to 40 per cent.; fixed carbon 40 to 50 per cent.

The Puget sound coals are suited to a variety of purposes. The output of some of the mines is used almost exclusively for steam generating purposes, as those of Franklin. Probably more coal is used for this purpose than for any other. A large quantity is used for domestic purposes. Coke making is becoming quite a large industry and several of the mines use a large part of their output in their coke ovens. The coke finds a ready sale, being more suitable for certain purposes. The only coal now used for gas making purposes is that found at Burnett. It is used exclusively in the Sound cities and in Oregon and California. It gives off a high percentage of illuminating gas and the residue cokes readily. A small vein of coal has been found at Fairfax suitable for blacksmithing and this finds a market at a high price.

Eastern Washington is largely supplied by the Roslyn mines which are the largest in the state. A considerable quantity of this coal finds its way to Seattle, where the company has recently erected large coal bunkers to take care of their export trade. A large part of the coal of western Washington is shipped to San Francisco and other coast ports. A considerable quantity is shipped to Alaska. The rise of the petroleum industry in California has caused a considerable falling off of the coal trade with the latter section. In the coastwise trade the coal of Washington competes with that of British Columbia and Oregon.

WHATCOM COUNTY.

In the western part of Whatcom county, extending from the foot of Mt. Baker to the coast, there is an area of Eocene coal

measures embracing over 250 square miles. These coal measures are composed mainly of massive sandstones and conglomerates, and shales, and are exclusively of lake origin. They have a total thickness of many thousands of feet. Within them very much vegetal matter in the form of lignite or coal is to be found, often in irregular masses or pockets, but now and then in a well-defined seam. Occasionally these seams assume dimensions sufficiently large to afford workable coal, and they are then of economic importance. In all cases, as far as known, the beds of coal are not immediately underlaid by clay, but by conglomerate or sandstone, showing that the coal was not formed by the plants which grew upon that particular spot, but rather that it was formed from drift wood. As a result no individual seam of coal can be expected to extend throughout the coal basin, or even over a large part of it, but is more local in its extent. It is also true that a coal seam will show considerable variability in thickness when followed in different directions.

Since their deposition the coal measures have been greatly folded and the strata are now inclined at high angles. Erosion has removed large portions of them, as may be seen in the wide valleys of the Nooksack and its tributaries, in the basin of Lake Whatcom, and elsewhere. In the eastern and central parts of the Whatcom coal field the strata outcrop everywhere and the coal beds may be easily found, but in the western part of the coal field the rocks pass under a heavy mantle of glacial drift and may only be studied or prospected by diamond drilling.

In the Whatcom coal field veins of workable coal have been found at a number of places. In some instances extensive mines have been opened and large quantities of coal produced. In a general way the coal may be said to improve in quality from west to east, as one passes from the region of least folded rocks to those that have suffered the greatest deformation. The coal vein now being developed on Cornell creek, within six miles of Mt. Baker, is said to be of a better quality than any other so far found in this field.

The Bellingham bay coal vein is the uppermost one in the Whatcom coal field. It is 14 feet thick, a lignite in quality, and was extensively worked 20 years ago. Its outcrop is north through the middle of the city of Whatcom and thence northwesterly, dipping west and southwest from 8 to 10 degrees.

Blue Canyon District.

The Blue Canyon mine is located on the southeastern shore of Lake Whatcom, on the railway of the Bellingham Bay Improvement Company. The vein of coal that is being worked varies much in thickness, but averages about 7 feet. It lies at the very base of the coal measures, being separated from the mica schist lying below by a layer of conglomerate which varies from six inches to three feet in thickness. Where the conglomerate is thinnest the coal vein is greatly broken and shattered, and is occasionally faulted. Lying as it does between the massive sandstones above and the metamorphic rocks below the vein has suffered greatly in the deformation of the coal measures. The vein pitches to the northwestward at an angle of 50 or 60 degrees.

The Blue Canyon mine has been in operation for a number of years, but has done little more than supply the demand of the cities and towns of Bellingham bay and thereabouts. The coal is very desirable for steaming and for domestic purposes. In 1901 the output of the mine was 48,200 tons.

SKAGIT COUNTY.

In the western half of Skagit county coal measures of Eocene age outcrop at a number of places. Surrounding these outcrops, as a rule, there are small coal basins, which seemingly have never been connected but have always been separated one from another. In the northwestern part of the county the large coal field of Whatcom county extends into Skagit for a little way. A mile west of Thornwood, on Samish river, there is an outcrop of coal where a little development work has been done. Immediately east of Montborne there is a small area of coal measures with a few coal outcrops. Near Cokedale and Hamilton there is in each case a coal measure area in which well known veins of coal occur.

The coal-bearing rocks above mentioned are composed essentially of shale, sandstone and conglomerate, with very much irregularly embedded vegetal matter in the form of lignite or coal. These deposits have been made in lakes which were enclosed in basins of metamorphic rocks, mainly schists and slates. After the lake sediments accumulated to a great thickness they were folded to such an extent that the strata are now often inclined at high angles. Since the disappearance of the lakes the

lacustrine sediments have been largely removed by erosion, and it is possible that the removal has been so great in the cases of the smaller lake deposits that some of these have not yet been discovered.

Cokedale District.

At the town of Cokedale a coal mine has been in operation for a number of years. The mine is located at the extreme northern limit of the coal basin, the lowest vein of coal being but a few feet from the schist which lies below. The coal measures of Cokedale outcrop along the northern boundaries of the district, but for the most part they are covered by the alluvial deposits of the Skagit river. The district is not believed to be a large one, extending from Cokedale southward to the Skagit, and in an east and west direction from near Lyman to a point a little way beyond Sedro-Woolley.

At the Cokedale mine three veins of coal are found, viz.: the north or Klondike vein, the middle vein, and the south vein. The north vein is the lowest one in the series and has a thickness varying from 10 to 25 feet; the middle vein lies 140 feet above the north vein, stratigraphically, and has a thickness of from 4 to 8 feet, with an average of 6 feet; the south vein, lying 40 feet above the middle vein, has a thickness varying from 6 inches to 2½ feet. The north and middle veins only are worked at the present time.

The Cokedale coal veins at their outcrops stand about vertical, but in the lower mine workings they dip slightly to the southward. In the deformation of the coal measures the coal was so greatly broken that in mining it it is obtained only in small pieces, and never in large lumps. It is a good coking coal, and a large part of it is made into coke. The coal is all passed through washers after leaving the mine; the coarser part is then used for steaming and domestic purposes, while the finer part is taken directly to the coke ovens near by. The ovens are of the bee hive pattern, each having a capacity of five tons. Forty ovens are in place, ten of which were operated continuously during 1901. In 1901 the output of the Cokedale mine consisted of 12,643 tons of coal and 5,806 tons of coke.

Hamilton District.

A few miles east of the Cokedale district, and near the town of Hamilton, is a region of coal-bearing rocks known as the

Hamilton district. This district lies chiefly between Cumberland and Day creeks, and extends from the Skagit river to the neighborhood of Deer creek. The rock outcrops of the Cokedale and Hamilton districts, are separated by the broad alluvial plain of the Skagit, and it is not known at the present time whether the coal-bearing rocks extend from one district to the other.

At several places in the Hamilton district coal veins of commercial importance are known to outcrop. Upon some of these veins considerable development work has been done, and in times past some coal has been mined and sold. The coal is of good quality, and of a variety that may be made into coke. As a rule the coal veins lie in such a position that they may be worked very readily.

On the property of the Skagit Cumberland Coal Company and on the lands of Mr. J. J. Conner, near the mouth of Cumberland creek, there are a number of outcropping coal veins. The first of these is located on the bank of Cumberland creek, not far from the contact of the coal measures with the underlying mica schist. This vein of coal has a strike of south 43 degrees east, and a southwest pitch of 55 degrees. It lies between sandstone walls, and has a thickness of about seven feet of clean coal. About a hundred feet stratigraphically above the vein just mentioned, is a second coal seam having approximately the same dip and strike, with a thickness of over five feet. Above the outcrop of the number two vein, at varying heights on the mountain side, there are outcrops of several other veins of coal with thicknesses ranging from a few inches to four feet.

Toward the southern part of the Hamilton district, in the region about Day lake, coal outcrops at a number of places. In a few instances some development work has been done. In sections 13 and 24 T. 34 N., R. 6 E., the coal veins have a thickness varying from 8 to 12 feet.

KING COUNTY.

Newcastle-Issaquah District.

The Newcastle-Issaquah district probably constitutes one continuous coal field. The Issaquah mine, formerly known as the Gilman mine, is located at the northern base of Squak mountain, two or three miles from the southern end of Lake Sammamish, and about fifteen miles east of the city of Seattle.

Squak mountain is a mass of volcanic rock of the variety known technically as pyroxene andesite. The coal measures overlie the lava and dip to the northward at an angle of from twenty to forty degrees. The strike of the strata is nearly due east and west. Only one fault of any consequence has been encountered in the Issaquah mine, and that has not seriously interfered with the process of mining. In this mine the workings have been pushed westward through Squak mountain, under the valley of Tibbetts creek and into the Newcastle hills.

A branch line of the Northern Pacific Railway reaches Issaquah by way of the northern end of Lake Washington, and the coal is shipped by that route. The mine was opened by the Issaquah Coal and Iron Company in 1887. Their holdings embrace a tract of land five miles long by one and a quarter miles wide. Up to the present time they have worked out about three hundred and twenty acres of coal, and have produced altogether about 1,500,000 tons of coal. The output for 1901 was 121,829 tons. It is expected that the output for 1902 will be considerably larger. There are seven known veins of coal on the property having a thickness respectively of four, five, six, eight, nine, twelve, and fourteen feet.

According to the statement of C. F. Owen, State Inspector of Coal Mines, the coal generates very little gas and can be worked in safety with open lights. It is used very largely for steaming and domestic purposes.

On the Newcastle side of the mountain the principal openings have been made along Coal creek, a small stream flowing northwestward into Lake Washington. Most of the coal has come from the vicinity of the town of Newcastle, where it has been mined extensively for the last forty years. These mines are among the oldest in the Puget sound region and have up to the present time produced about five millions of tons. The coal is taken out by way of the Columbia & Puget Sound Railway, which reaches Seattle by way of Renton and the Duwamish valley. Both mines and railroad belong to the Pacific Coast Company, formerly the Oregon Improvement Company. The present Newcastle mine was opened in 1895, and is now practically worked out. It has produced altogether nearly 600,000 tons of coal. There are five veins, having a width of three feet four inches, four feet, four feet six inches, six feet and eight feet, re-

COAL BUNKERS, SEATTLE

spectively, and there are about ten miles of gangways and slopes. The breast and pillar system has been employed in the mine. Most of the coal is used for domestic purposes and for generating steam.

Since the Newcastle mine has been virtually abandoned active operations have been transferred to the new Coal Creek mine about a mile and a half farther up the stream. This mine was opened in 1898 and up to January 1, 1902 had produced about 300,000 tons. The daily output is now on an average 750 tons. For the year 1901 the total output was 130,957 tons. Four veins are being worked, two of them three feet eight inches in width, one four feet two inches, and one five feet. In the present workings the veins strike approximately east and west and dip north thirty-eight degrees. A double track working tunnel, seven by fourteen feet in diameter, has been driven a distance of 5,400 feet. There are altogether about three miles of gangways. In the main tunnel electric motors are employed for hauling, and electric lights are used. The breast and pillar system is the one adopted. A 375 h. p. plant generates electricity for hauling, lighting, ventilating, running the air compressor, running the washing machines, etc. The company uses a rotary washer of their own manufacture.

Renton-Cedar River District.

The depression occupied by Lake Washington is continued southward first as Black river valley, and then as White river valley. Less than a mile from where Black river leaves Lake Washington Cedar river enters the former from the eastward, flowing through a narrow, steep-sided valley for a number of miles and entering the broader valley at the town of Renton. Between the valleys of Cedar river and White river there is a plateau which from the surface indications seems to be composed entirely of glacial drift. It has an average elevation of about four hundred feet above the level of the bordering valleys. Along the steep sided northern and western edges of this plateau, especially near the town of Renton, the coal measures outcrop from beneath the covering of glacial drift. Seven or eight miles farther up the valley of Cedar river the coal-bearing rocks are again exposed where the Cedar mountain mine has been opened. On the northern side of Black river between

Renton and the Duwamish river the coal measures appear in a nearly horizontal position.

The first mine to be operated on an extensive scale in the vicinity of Renton was the old Renton mine, which was opened by a number of Seattle pioneers early in the seventies. This mine has long since been worked out, as has also the Talbot mine, opened a year or two later. In 1895 the Renton Co-operative Coal Company began operations on a tract of unoccupied ground between the two old mines. They afterwards sold out their property to the Seattle Electric Company. The new owners are now working on two veins, No. 2 and No. 3, each of which is about six feet thick, and they are driving a tunnel to open a third vein. There are about 9,000 feet of underground main tracks. The pillar and stall method of mining is employed. At present the daily output averages about 400 tons, and the total output for 1901 was 72,865 tons. The coal is used mostly for steaming and domestic purposes. It is washed by means of Howe washers. All the hoisting, pumping and lighting is done by means of a 150 h. p. electric plant.

Eight or nine miles up Cedar river from Renton is the Cedar mountain mine. The first openings in this vicinity were made about twenty years ago and for a long time the mine was a great producer, but the principal vein was lost and has only recently been rediscovered. The Cedar Mountain Coal Company obtained control of the property in 1898 and since that time has been working on an eight-foot vein. The total output for 1901 was 13,500 tons.

Green River District.

A thick section of the coal measures is exposed in the canyon of Green river, T. 21 N., R. 6 and 7 E. There are altogether forty beds of carbonaceous matter included in this section, but only four of them are productive coal beds. These outcrops were discovered about 1880, and two or three years later the Franklin and Black Diamond collieries were opened. The only vein that is now worked very extensively is the McKay vein, otherwise known as the Light Ash or White Ash vein. The strata in this district are thrown into long open folds, and the whole series inclines to the southwest. Several faults have been encountered in the course of mining and in each case the hanging wall has slid downwards. Three of these normal faults

occur in the Black Diamond mine. In the Franklin mine there are a number of small faults. In the eastern part of the field where the greatest disturbance has taken place in the rocks the coal has become highly bituminous, while in the northwestern section where the rocks remain more nearly in their original position, the coal remains a lignite.

The Gem mine at Franklin, belonging to the Pacific Coast Company, was opened in 1899 and has, up to date, produced 75,000 tons of coal. The total output for the year 1901 was 36,460 tons. It has now a daily output of 180 tons. The vein which the company is now working has a thickness of two feet seven inches of good, clean coal. In the present workings the vein strikes nearly due north and south and dips thirty-five degrees to the west. It is said that the vein can be traced for three miles on the surface of the ground. An estimate of the coal still to be mined places the amount at about 2,500,000 tons. The total length of underground workings is not far from 3,000 feet. A 75 h. p. steam engine is used for hoisting and ventilating. The chute and pillar system of mining is employed altogether.

The Franklin No. 1 and No. 2 was operated for a number of years, but was flooded and abandoned some time ago. It is now being reopened and will be operated again on an extensive scale in the near future. Since starting again it shipped, prior to January 1, 1902, 4,494 tons, and has now a daily output of 50 tons. Two veins are being worked, one four feet and the other nine feet in thickness. They are worked on the chute and pillar system. A 500 h. p. steam plant is employed for hoisting, ventilating, pumping, and operating the coal washing machinery. It also runs the air compressor, which is used for running the drills and other mining machines. The coal washers are of the rotary pattern and are the company's own manufacture. The coal is nearly all used on locomotives and steamers. The mine is the property of the Pacific Coast Company.

Franklin No. 7, opened in 1895, has produced about 700,000 tons of coal up to the present time and has now a daily output of 300 tons. The the total output for the year 1901 was 88,217 tons. One vein is being worked which has a thickness of four feet six inches. There is a 500 h. p. plant for hoisting, pumping, ventilating and lighting. The slope has now been driven in a distance of 3000 feet and there are altogether about five

miles of gangway. Electricity is used for lighting wherever possible. The breast and pillar system of mining is employed. The coal is used largely for steam generating purposes in steamers and manufacturing plants.

The Lawson mine near Black Diamond, which is also the property of the Pacific Coast Company, was opened in 1895 and has had a total output up to the present time of 260,000 tons. The company is working on vein No. 1, better known as the McKay vein, which is four feet and four inches in thickness, all of clean coal. There is now being mined on an average 400 tons per day. The coal is used very largely on steamers and in factories; also for domestic purposes. There are now three miles of underground gangways, and a slope fourteen hundred feet long. All the mining is done on the chute and pillar system. Steam power of 375 h. p. is used for operating the hoisting, ventilating, pumping and other mine machinery. Electricity is used for lighting wherever possible. It is estimated that the mine still contains about 5,000,000 tons of coal. For the year 1901 the output was 97,329 tons.

The Black Diamond mine was first opened about nineteen years ago. The property is now being operated from two openings on the McKay vein, known as Mine 14 and Morgan's Slope. The coal is good, clean steaming coal and requires very little picking or washing. It produced in 1901, 227,000 tons.

The Seattle & San Francisco Railway Company's mine at Ravensdale, formerly known as Leary, was opened two or three years ago when the district was given transportation facilities by the construction of the Palmer cut-off of the Northern Pacific railway. It is situated seven or eight miles west of Palmer. Four veins are now being worked. Prior to 1901 the mine shipped 48,000 tons and for 1901 the total output was 63,578 tons. The company has lately constructed large coal bunkers at West Seattle.

PIERCE COUNTY.

Wilkeson-Carbonado District.

This field lies about midway between the city of Tacoma and Mount Rainier. All of the producing mines are in the extreme northern part of the field and not far from the main line of the Northern Pacific Railway. Carbon river, which derives its name from the numerous outcroppings of coal along its course, flows

for about eight miles through the district. Just above the town of Carbonado the river flows through a steep sided canyon in volcanic rock, but at the town and for a mile or two down the river the coal series is exposed. Other sections occur along Gale creek and South Prairie creeks, tributaries of Carbcn river. The hills are covered with glacial drift to a depth of from fifty to three hundred feet. In addition to this the whole region is very heavily timbered, so that surface prospecting can be carried on only along the stream channels. Measurements made by Mr. Bailey Willis,* of the sections exposed along the streams and in the mine workings showed a thickness of 8,000 feet of barren measures lying above the productive coal beds.

Coal was first discovered on Carbon river forty years ago, and the first location was made by Flett Brothers and their brother-in-law Gale, about ten or twelve years later, that is, in 1874. They made the first opening on Gale creek about half a mile above the present town of Wilkeson. A wagon road was constructed from South Prairie to the mine and a number of tons of coal hauled to Tacoma.

The Burnett mine is the most northerly one now operated in this field. It was opened by Mr. C. H. Burnett in December, 1881, and has now passed into the hands of the South Prairie Coal Company. A short branch line connects the mine with the Northern Pacific Railway at Cascade Junction. Four veins have been worked to a greater or less extent, but there are only two at present from which coal is being taken. They are both about three feet in thickness. The total output since the mine was first opened is estimated at 930,000 tons. At the present time about 300 tons per day are being shipped. The total length of underground workings is at least two miles. The coal is used for domestic purposes, for steaming, and for the manufacture of gas. The coal is washed by means of Howe washers. A 300 h. p. steam power plant is employed for hoisting, pumping, etc. Seventy-seven thousand two hundred and fifty-five tons were produced in 1901.

The Wilkson mine, operated by the Wilkeson Coal and Coke Company, is on a branch line of the Northern Pacific railway about thirty-one miles from Tacoma and two miles south of Burnett. It was opened in 1879 and at the present time there are

* Willis: Coal Fields of Puget Sound, 18th Ann. Rep. U. S. Geol. Survey.

about six miles of water level gangways. The estimated total output since the mine was started is 1,000,000 tons. The daily output now is 500 tons. Six veins are being worked, having an average thickness of six feet each. The chute and pillar system of mining is employed. Forrester patent washers are used. The power consists of two steam stationary engines of 130 h. p. and two locomotives. Mules are employed underground. The company has a large coking plant in operation and most of the output of the mine is converted into coke. There are fifty ovens built on the bee hive pattern, twelve feet in diameter, which turn out about seventy tons of coke per day. Fifty more ovens are being erected which will give a total daily output of 100 tons. In the year 1900, 47,615 tons of coal were converted into 29,309 tons of coke. For the year 1901 the total output was 125,028 tons of coal. The veins which are now being worked outcrop on the surface along Gale creek in the western part of section 27. The strata here are bent into a broad, low arch with a number of smaller folds. Operations have been conducted on each side of the main arch and a number of faults have been encountered. The present company operating the mine owns the land on the western side of the arch. On the eastern side where the veins dip to the eastward the land belongs to the Northern Pacific Railway Company, but is worked by the Wilkeson Coal and Coke Company on a royalty in connection with their own property. Only one quarter of the available coal above water-level has been worked out and there are several millions of tons below water-level that can be mined at a profit.

The Carbonado mines are opened about two miles south of Wilkeson on Carbon river, which here flows through a canyon about three hundred and fifty feet deep. The railroad was extended from Wilkeson to Carbonado about the year 1880 and shipments of coal at once began. Four veins are now being worked which have a thickness of four feet six inches, five to six feet six inches, five feet, and seven feet four inches respectively. The total output has been over four millions of tons. The output for 1901 was 323,395 tons. A battery of 75 coke ovens is being installed.

The Gale Creek Company and the Willis Coal Company are opening up new mines in the district. The Gale Creek Company is working five veins from three to seven feet thick, and

has taken out about one hundred thousand tons of first-class steaming and gas coal. Their output for 1901 was 18,900 tons. The Willis company has six veins, from three to six feet thick, and has taken out several thousand tons.

The Western America Company, operating the Fairfax coal mine, has built a railroad seven and a half miles long to connect with the Northern Pacific at Carbonado. They began operations in January, 1900, and are now producing about two hundred tons per day. For the year 1901 their output was 30,513 tons. Three veins are being worked: No. 2, six feet thick, No. 3, six feet eight inches thick, and Blacksmith vein, two feet six inches thick. A water-power plant of 125 h. p. is used to generate electricity for lighting, hauling, etc. There are now about 3,000 feet of gangways with smaller workings to match. The diamond system of mining is principally employed. The company has gone into the coking industry on an extensive scale. They have now in operation sixty bee-hive ovens thirteen feet in diameter and seven feet in height. Besides being made into coke, the coal is very largely used for blacksmithing and for steam making.

The Montezuma mine has been opened in section 2, T. 17 N., R. 6 E. Work was begun in February, 1901, and up to the present time about 800 feet of entries and airways have been driven. No attempt has yet been made to stope out the coal and no shipments have been made, but in the course of driving the entries from twenty-five to thirty tons of coal per day are taken out. The long wall system of mining will be employed. The company has ordered one hundred bee-hive coke ovens and as soon as these arrive most of the output of the mine will be converted into coke. A 400 h. p. turbine wheel has been installed, and all the hoisting, hauling, etc., will be done by water power. Three veins are being worked, having a thickness of three feet six inches, seven feet and nine feet, respectively. Two rock tunnels are being driven which will crosscut two or three more veins, one five feet, one nine feet and another of unknown thickness.

KITTITAS COUNTY.

Roslyn-Clealum District.

The Roslyn and Clealum coal field, situated in the northwestern portion of Kittitas county, on the line of the Northern

Pacific Railway, is separated from the coal fields of western Washington by the main range of the Cascade mountains.

The coal occurs in a series of light colored sandstones to which the name "Roslyn sandstone" has been given. This formation is underlaid by a series of sheets of basaltic lava, which in turn are underlaid by other sandstones. The thickness of the Roslyn sandstone has been estimated as at least 3,500 feet.* Fossil plants from the Roslyn coal mine and from other coal seams about Clealum have been identified by Professor F. H. Knowlton as being of Eocene age. This makes the Roslyn coal roughly contemporaneous in origin with the coals of western Washington.

The Roslyn coal mine, owned and operated by the Northwestern Improvement Company, is the largest in the state. A branch road three or four miles long runs from the main line of the Northern Pacific Railway at Clealum to this mine. The mine was first opened in 1885 by the Northern Pacific Coal Company, which was afterwards reorganized as the Northwestern Improvement Company. The coal vein is four feet eight inches in thickness and dips at Roslyn from thirteen to twenty-six degrees to the southwest. It is bituminous and an excellent steaming coal. The output for 1901 was 1,005,027 tons, having a value at the mine of over $1,500,000. Up to November 1, 1901, the total output since the opening of the mine was 5,826,727 tons, taken from an area of about one thousand acres. A conservative estimate of the Northwestern Improvement Company's holding of ten thousand acres places the total amount of coal still remaining at forty-seven millions of tons.† The Roslyn vein is supposed to extend under the entire Clealum valley at a depth of eleven hundred to fifteen hundred feet. It occupies a shallow syncline with an east and west axis.

The Clealum mine, operated by the same company as the Roslyn mine, was opened in 1894. The vein upon which they are now working occurs higher in the series than the Roslyn vein. It is from four and one half feet to five and one half feet thick and dips southward at an angle of about fourteen degrees.

The Ellensburg Coal Mining Company has operated a mine

* Geology of the Cascade Mountins in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

† 9th Biennial Report, State Inspector of Coal Mines, C. F. Owen, 1901.

NO. 4 OPENING AND ELECTRIC LIGHTING PLANT AT ROSLYN COAL MINES.

in a small way situated two miles north of Clealum. The vein is four feet thick.

Other coal outcrops occur on the Teanaway river north of Clealum, on Frost creek, on First creek, Naneum creek and on Williams creek.* Not much development work has been done on any of these properties, so it is not known at present whether or not the coal occurs in commercial quantities.

THURSTON COUNTY.

Bucoda-Tenino District.

The Bucoda-Tenino district lies in the southern portion of Thurston county. Its boundaries are not definitely fixed in any direction. A large part of its surface area is composed of flat river bottom and barren gravel plains, and it is only where the coal-bearing formation appears at the surface along the hillsides and on higher ground that it is possible to discover any outcroppings of coal.

Coal was first discovered in the valley of the Skookumchuck in 1855. It was mined in the vicinity of Bucoda in early territorial days, the convicts of the penitentiary being employed for that purpose. The early mines are now closed down and it is difficult to get definite information regarding them.

The Chehalis and Skookumchuck rivers flow through wide, level valleys. Hills of sedimentary rocks belonging to the coal-bearing series border the valleys and rise to heights of several hundred feet. During late glacial time the melting of the great ice mass which occupied the basin of Puget sound caused a tremendous flood of water to sweep southward over this region. This great river was heavily loaded with sediments of all degrees of coarseness, which it dropped by the wayside as it passed along. In the northern part of the field in the vicinity of Tenino the gravel is quite coarse, and water-worn boulders are scattered everywhere. Traveling southward into Lewis county the material gets finer and finer until in the vicinity of Chehalis it is a fine sandy loam with no gravel. South of Chehalis there are no signs of glacial action whatever.

The Great Western Coal Company, of Spokane, have a mine about four miles southwest of Tenino in section 35, T. 16 N., R.

*Geology of the Cascade Mountains in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

2 W. Considerable prospecting work has been done with a diamond drill. A tunnel three hundred feet long has been driven and crosscuts made. The vein upon which they are working is about three feet six inches in thickness. At the present time the coal is hauled to the railroad in wagons, and about two car loads a week are shipped. The coal is said to be of good quality. It is a lignite like all the rest of the coal in this field.

The Seatco coal mine was opened in 1880 near the town of Seatco, the name of which was afterwards changed to Bucoda. It was operated with convict labor taken from the territorial penitentiary, which was at that time located at Seatco. Public sentiment was hostile to the enterprise, however, so that the convict system was soon discontinued and the mine closed down. Of the original penitentiary company, composed of Messrs. Billings, Smith and Shead, Mr. Billings is the only surviving member. They operated on an eight foot vein of coal and took out altogether about ten thousand tons.

LEWIS COUNTY.

Chehalis-Centralia District.

The two towns of Chehalis and Centralia lie about four miles apart, on a wide river plain. Along the sides of the valley coal outcroppings have been found and a number of openings have been made, but none of them have developed into extensive mines. A little coal is being taken out to supply the local demand. Nearly all of it is used for domestic purposes. The electric power plant of Chehalis uses it for making steam.

In the hill back of the town of Chehalis a number of prospects have been opened up in the past. Several years ago prospects were opened up on the Rosenthal property, but they have since been closed. At the present time there is one small mine working about a mile from town in Sec. 29, T. 14 N., R. 2 W. It is operated by Miller Brothers. They have driven a tunnel about one hundred and twenty feet on a vein which measures four feet three inches in thickness and dips about forty-five degrees. They began work in October, 1901, and at the end of the year had taken out about four hundred and thirty tons. The coal is all sold in the town of Chehalis. It is a lignite of fair quality, but leaves a large amount of ash.

There is only one coal mine operating at present in the vicinity

of Centralia. It is the Salzer Valley Coal Mine, situated in Sec. 12, T. 14 N., R. 2 W., about four miles east of Centralia. This mine has been operated in a small way by Mr. Marion Howell for the last four years. For the last three months of the year 1901 the output was 267 tons. The vein is five feet six inches in width and lies nearly horizontal. A tunnel one hundred and fifty feet long has been driven. The coal is hauled in wagons to Centralia and Chehalis and sold for domestic purposes.

A new mine is being opened up by the Sterling Company in the Hanaford valley in T. 14 N., R. 1 W., about eight miles east of Centralia. A railroad will be built from the mine to the Northern Pacific Railway, a distance of a little more than nine miles. The junction will be about a mile and a half north of Centralia. The company owns nine hundred acres of coal lands. Three veins will be worked, the first seven feet four inches thick, the second fourteen feet thick, and the third five feet eight inches thick. The coal is a lignite and is said to have a low percentage of ash. At the point where the veins are being opened up they dip about eleven degrees from the horizontal.

The old Florence or Ellsbury mine is now closed down. It was worked for a number of years and had a total output of about ten or fifteen thousand tons. It was finally abandoned seven or eight years ago.

Some coal was taken out of another mine on Sec. 3, T. 14 N., R. 2 W., but it was also abandoned about four years ago.

To the eastward coal outcrops have been found at intervals nearly all the way to the summit of the Cascades. At several different places extensive development work has been done. In the western part of the field the coal is lignite, but as it approaches the Cascades it is said to develop into bituminous coal and finally into anthracite.

COWLITZ COUNTY.

Kelso-Castle Rock District.

The Kelso-Castle Rock coal field embraces nearly all of the northwestern part of Cowlitz county. The Cowlitz river runs north and south through the center of it. The country is, for the most part, very heavily timbered and the hills are worn into low, rounded forms so that the solid rock does not show in many places. The soft coal bearing rocks have been decomposed to

considerable depths and a residual soil many feet in thickness has been formed. For this reason the boundaries of these rocks are not definitely known. It is probable that as the district becomes better known the boundaries of the area of productive coal measures will be greatly extended.

Throughout this part of its course the Cowlitz river flows through a flat alluvial valley a mile or two in width, bordered by low hills which gradually increase in height as they recede from the river. The tide flows up the river several miles above Kelso. At Rocky Point and at Castle Rock bold bluffs of hard basaltic lava extend out into the valley. In the vicinity of Kelso and higher up the river there are the remants of a rocky bench or terrace about fifty feet in height above the level floor of the valley.

The coal bearing rocks are sandstones and shales probably of Eocene age. They have been upturned from their original horizontal position only to a slight degree. Along the Cowlitz river the rocks are thrown into gentle folds. A large number of coal seams have been found at different places varying from a few inches to six or eight feet in thickness.

The Anchor mine was opened in 1890 by the Anchor Coal and Development Company, of San Francisco. It is located in Sec. 13, T. 8 N., R. 2 W., about three miles northeast of Kelso. Two veins were worked, one about four feet and the other five feet in thickness. A narrow gauge railroad three-quarters of a mile long ran from the mine to the Cowlitz river where the coal was loaded on barges and shipped to Portland and other places. Although a large amount of money was spent, the mine did not turn out to be a success. It was finally abandoned about 1898.

The Coal Creek Development Company, of The Dalles, Oregon, is opening up a coal prospect on Coal creek, about eight miles west of Kelso. A standard gauge railroad is being built from the mine to tide water, a distance of four miles, where the coal will be loaded on barges and shipped to Portland.

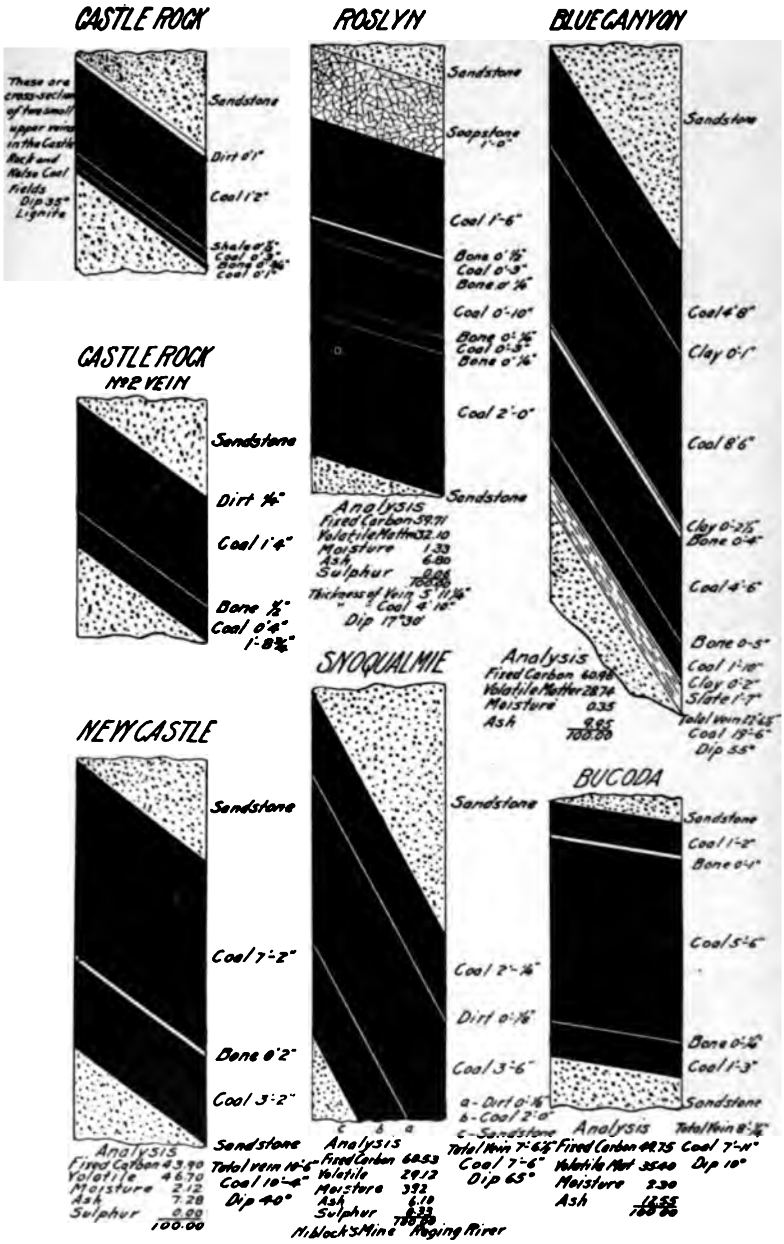
The Oregon Coal and Timber Company, Joseph Gaston, president, W. T. Webber, superintendent, has obtained possession of the old Idleman mine, situated in Secs. 12 and 13, T. 9 N., R. 2 W., about a mile and a half east of Castle Rock. The mine was first opened up by Mr. C. M. Idleman, a number of years ago. It was worked in a small way until 1893, when it closed down on account of litigation. The new company began

operations late in the autumn of 1901. The old workings have been pumped out and preparations are now being made to develop the mines on an extensive scale. Several veins are being opened up, one four feet six inches, another four feet one inch, and a third six feet in thickness, respectively. Still other veins of unknown thickness outcrop at points below. A standard gauge railroad from the mine to the Cowlitz river is partly completed. An incline seven hundred feet in length has been driven and a number of crosscuts made. The coal is a brown lignite with very little sulphur and a small percentage of ash. It will be shipped in barges to Portland.

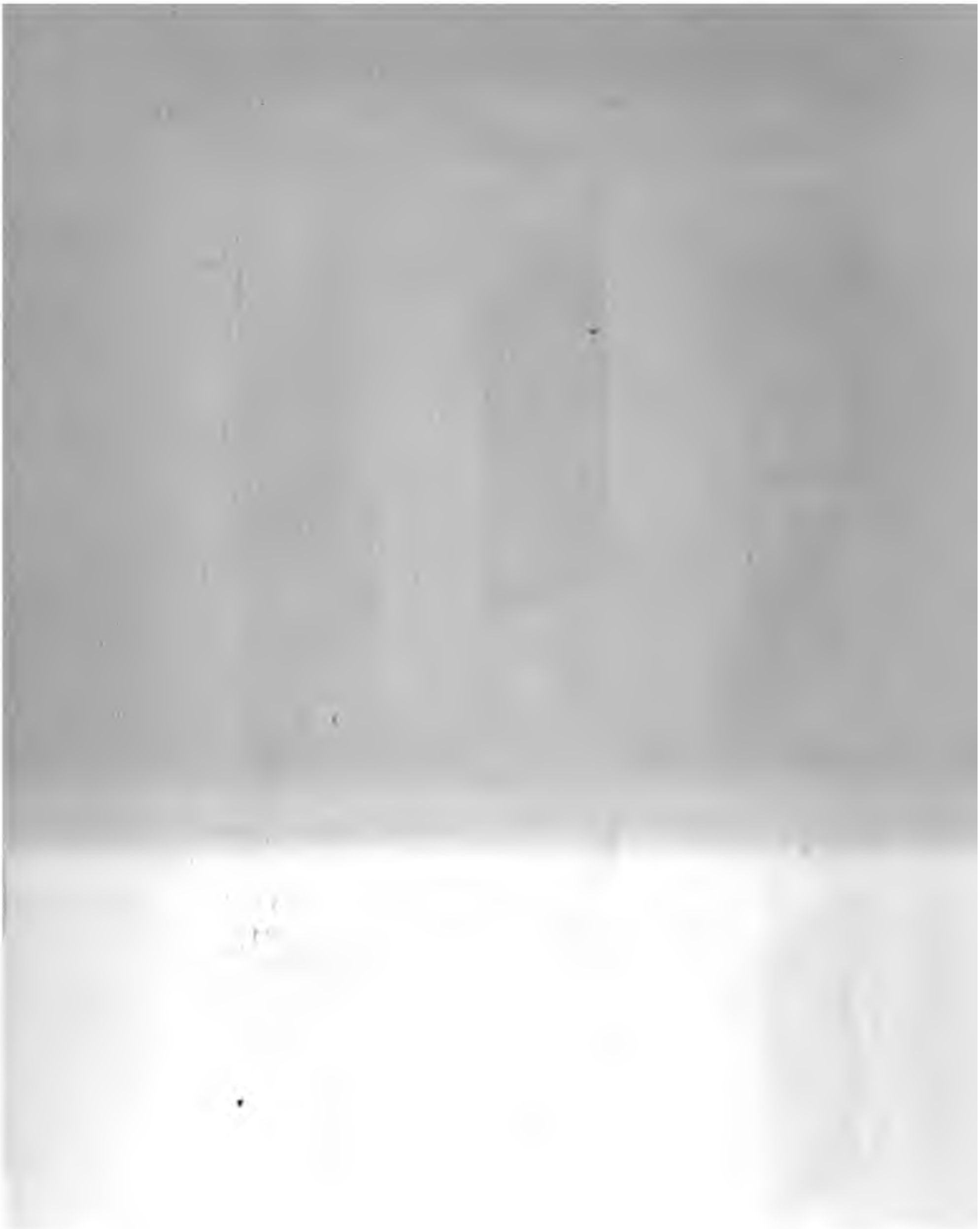
Another mine known as the Red Ash mine was opened up several years ago on Arkansas creek, about two or three miles west of Castle Rock. A considerable amount of coal was shipped to Portland and other places, where it is said to have given good satisfaction. It was closed down about two years ago, but negotiations are now pending whereby it will be opened again. The vein that was worked is said to be seven feet in thickness. A shaft has been sunk and an incline one hundred and fifty feet in length driven on the vein.

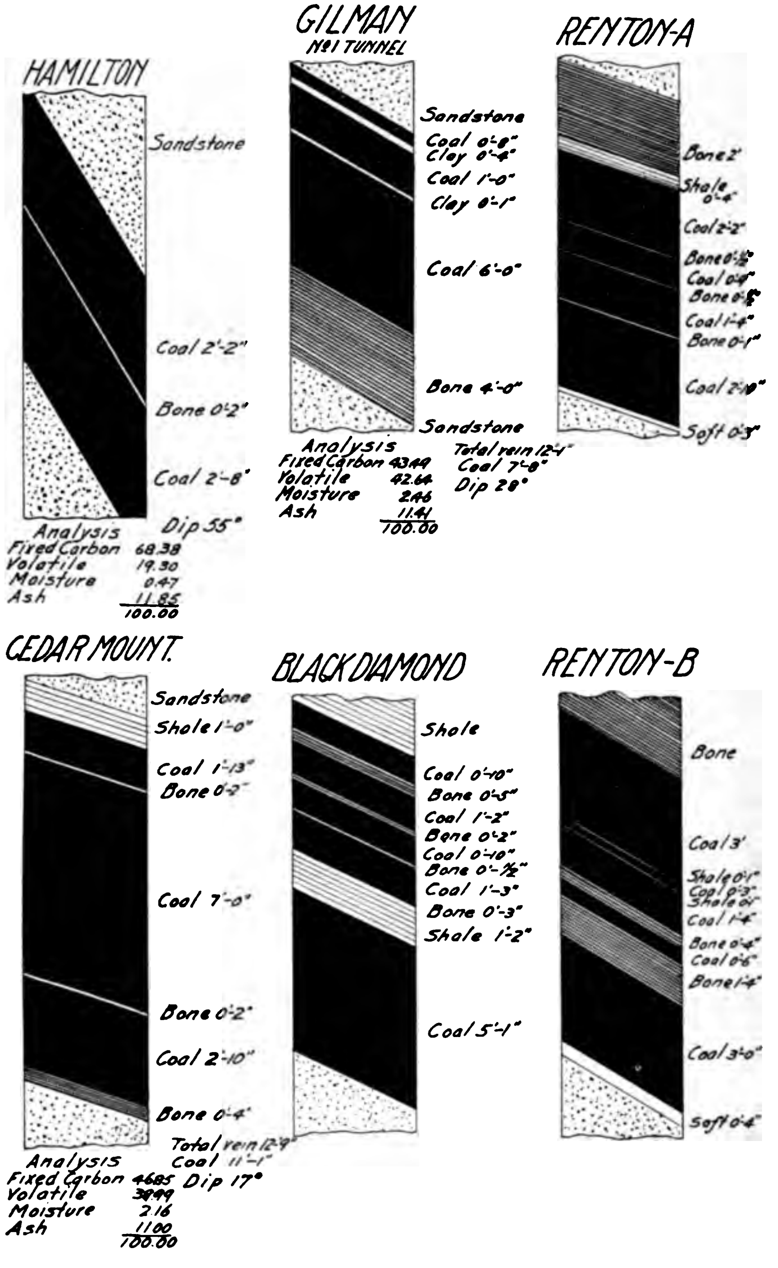
The Carbondale mine, three miles southeast of Castle Rock, in Sec. 24, T. 9 N., R. 1 W., has been developed to some extent. It belongs to Portland parties. No coal has yet been shipped from this prospect.

Another prospect upon which work has been done lies in the NW. ¼ Sec. 24, T. 10 N., R. 1 W., on Toutle river, three or four miles from the Cowlitz. Other prospect holes have been sunk on Sec. 24, T. 9 N., R. 1 W., and in Secs. 8 and 18, T. 10 N., R. 1 E.



SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.





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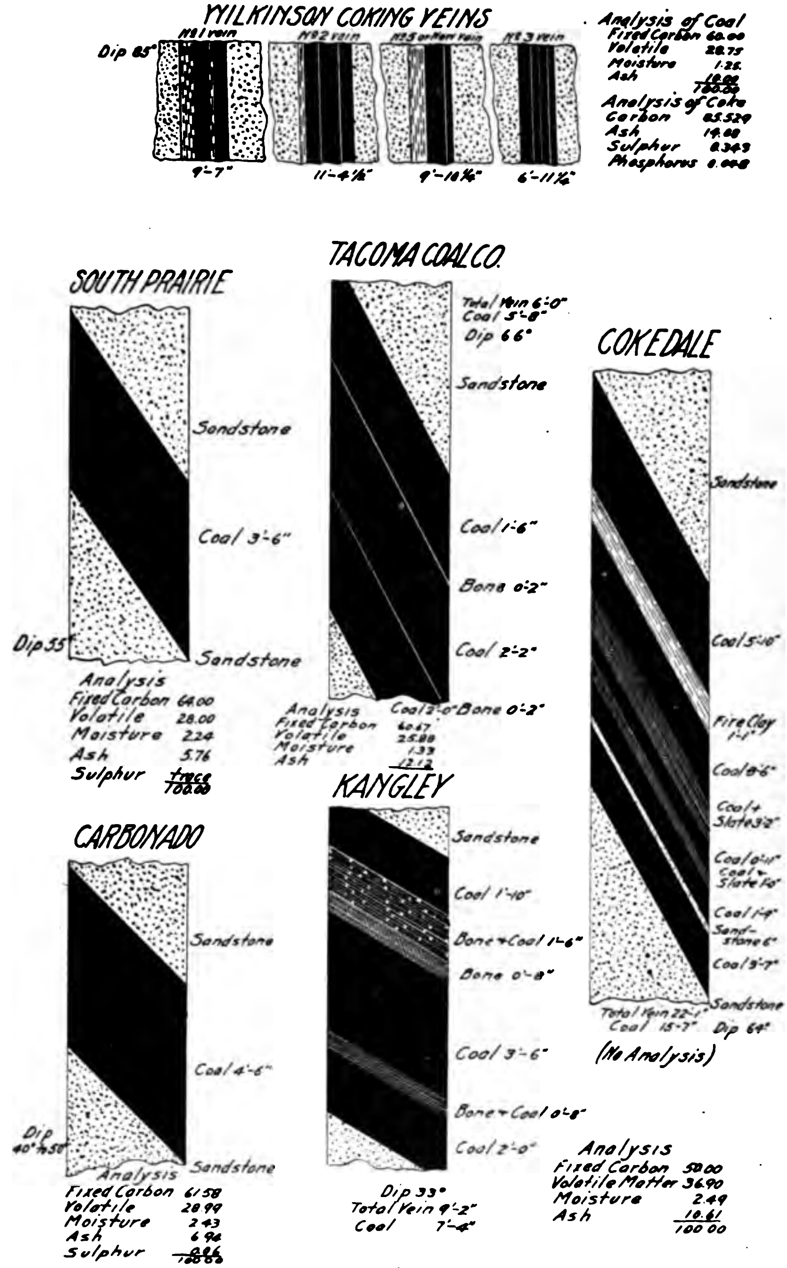

SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.

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WASHINGTON

GEOLOGICAL SURVEY.

HENRY LANDES, STATE GEOLOGIST.

VOLUME I.

ANNUAL REPORT FOR 1901.

IN SIX PARTS.

PART V.

THE WATER RESOURCES OF WASHINGTON.

POTABLE AND MINERAL WATER.

BY H. G. BYERS.

ARTESIAN WATER.

BY C. A. RUDDY.

WATER POWER.

BY R. E. HEINE.

OLYMPIA, WASH.:
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1902.

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Late Professor of Mining Engineering and Metallurgy, University of Washington.

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ILLUSTRATIONS.

PREFACE.

It is felt that an outline, or any description of the mineral resources of Washington would be incomplete without some mention of the incomparable water resources of the state. Therefore articles have been prepared for this report dealing with the potable and mineral waters, artesian waters and the water power of Washington.

In POTABLE AND MINERAL WATER, by H. G. Byers, some statements are made concerning drinking water in general, followed by a discussion and the analyses of the drinking water of the various cities of the state. Comparisons are made with certain potable waters found elsewhere. Descriptions are given of the principal mineral springs, including analyses of their waters, temperature, etc. At the time this article was written some of the mineral springs were inaccessible, and hence cannot be described until a later report. A partial study was made of the alkali lakes in the hope that the water might be sufficiently concentrated to be of economic value. From the analyses such does not appear to be the case.

In ARTESIAN WATER, by C. A. Ruddy, after some general statements concerning artesian basins, the leading artesian districts of eastern Washington are described. In any arid district the possibility of artesian water is a matter of great interest because of the necessity of water for irrigating purposes. It is hoped that there will be an opportunity for investigations throughout the arid and semi-arid portions of central Washington, so that all the artesian basins may be discovered and described, in order that their storehouses of water may be unlocked.

In WATER-POWER, by R. E. Heine, after some introductory statements concerning the latent water-power of the state, brief descriptions are given of the best known water-power plants. All of these plants have been only lately put in operation, and it is thought that they but mark the beginning of a development which will prove a tremendous factor in the commercial advancement of the state.

We were led into this investigation by the fact that, when recently arrived in the state, we were called upon to pronounce upon the purity of the water of the city of Chehalis. It was then learned that there were no records of analyses upon which to rest a comparison, and therefore no local data upon which to base a decision. No funds were at our disposal yet we nevertheless started to accumulate such data and deeming that the most valuable information was to be gleaned from the investigation of the city supplies, our work was almost exclusively upon them.

In making these analyses we omitted no reasonable precaution to secure results which are accurate and conclusive. The waters, where possible, were collected by ourselves, and in all other cases careful instructions were given to persons who collected the samples for us. As soon as possible after the receipt of a sample the analysis was begun and was usually completed upon the same day. The methods of analysis were those employed by the Massachusetts Board of Health or by the Illinois State Survey. Nearly all the samples were collected between November 13, 1900 and May 1, 1901, and so represent winter conditions. The results of similar analyses of summer waters would add greatly to the value of the report.

The results were surprising in many cases because of the great purity of the waters, and hence it seemed interesting to compare our results with similar analyses of the water supplies of eastern cities. These were obtained from New York, Chicago, St. Paul, Minneapolis, New Orleans, Boston and other places. No results could be obtained from San Francisco and Portland because no analyses have been made. St. Louis failed to send any results. The value of such work is shown by the fact that the city of Chehalis now secures its supply from a purer source and the city of Ballard will probably secure an extension of the Cedar river system which furnishes the supply of Seattle. It is clear also from our analyses that the limits of permissibility as laid down by the Illinois survey for the waters of that state do not hold here. The results of our analyses are given in the accompanying table.

The results which are given in parts per million are in terms which, for the most part, are unintelligible to the general public, therefore a discussion of them is necessary.

It is well known that water in nature is never pure, but contains in solution various substances upon the character and quan-

THE WATER RESOURCES OF WASHINGTON.

POTABLE AND MINERAL WATER.

BY H. G. BYERS.

CITY WATER SUPPLIES.

Water surveys have been or are being made in many of the states. These surveys are for the purpose of determining the sanitary condition of present supplies, of the formulation of standards of purity of unpolluted waters, and of enabling citizens to gain immediate and authoritative information in regard to the potability of any source of supply. These surveys are made at the expense of the state and are in some cases of great extent and corresponding value.

That an abundant supply of pure drinking water is very important for the preservation of health, and that impure water is a most potent factor in the development and spread of disease, are propositions the truth of which is unquestioned by physicians, scientists or the general public. It is not a matter of general information, however, that local conditions greatly modify the deductions to be made from a given analysis, and that such results as would in certain circumstances indicate unsanitary water would in other cases indicate no such condition. For example results which if obtained from the water of deep wells would indicate certainty of contamination would carry no such significance if the water were from surface drainage.

The water supplies of the state are from three sources—rain, deep wells, and surface drainage; this last includes shallow wells and springs. Of these surface drainage waters are by far the most important since but few people use rain water directly and but few deep wells have been sunk. The report in this case therefore deals only with surface waters.

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It is well known that water in nature is never pure, but contains in solution various substances upon the character and quan-

tity of which depends the potability of water. Rain water as it falls from the clouds is probably the purest obtainable without distillation, but even this contains dust particles and gases washed out of the air. As soon as water reaches the earth it begins to dissolve more or less of all the substances with which it comes in contact, becoming impure with harmless, harmful or beneficial ingredients. In well peopled regions the water courses are often simply sewers which convey away or assist in the destruction of the refuse organic matter of the surface. Springs many times contain besides the mineral matters over which they pass, some of the vegetable or mineral matters through which the water has percolated in reaching their sources. In the case of wells contamination is usually due to the nature of the soil in which they are sunk, but may be added to by the infiltration of sewage from cesspools or privy vaults which not infrequently are situated in close proximity to the wells. In such cases the purifying influence of the earth is relied upon, but which, while undoubtedly great, is very frequently over estimated.

The fact that the water of a given source of supply is clear, is as is well known, no certificate of its purity; though lack of clearness, while not a certain indication of *dangerous* contamination, is certainly not a desirable condition. It is true also that clear sparkling water contaminated by sewage may sometimes be used for a long time without harm to the users. No one, however, would knowingly use such water simply as a matter of taste, yet there is the additional fact of the constant danger of the introduction of germs of contagious diseases where the contamination is of animal nature. Such being the case water which is impure with, or subject to contamination from, matter of animal origin is more dangerous than water rendered foul with decaying vegetable matter. In the latter case, however, an excessive amount of impurities is not considered healthful and is to be considered as rendering a water unfit for use. From all these facts it is clear that it is necessary for an analyst, in order to form the most useful conclusion from the result of his analysis to know as much as possible about the history of the water involved, the nature of the soil through which it passes, and the location of surrounding sources of infection.

All waters, except in special cases, contain the same substances and it is upon the varying quantities of these that a

judgment is based. The substances usually sought in a chemical analysis, *i. e.*, those which bear relation to sanitary conditions and the amount which it is possible for a water to contain and remain fit for drinking purposes are given in the subjoined table, which is taken from the report of the Illinois Survey:

	Parts per million.
Total solids	500.
Loss on ignition (no blacking should occur and no offensive odor develop)	....
Oxygen consumed	2.
Chlorine	15.
Nitrogen as free or saline ammonia	0.02
Nitrogen as albumenoid ammonia	0.05
Nitrogen as nitrites	0.001
Nitrogen as nitrates	15.

These figures are of course only approximate, even for Illinois, and are but a good general guide. It is to be noted that judging by our analyses the limit for chlorine and nitrates is several points too high, while the limit for ammonia content is too low.

The total solids of a water are not of very great importance unless they are in such quantity as to be detrimental because of that fact or because of their nature as determined by subsequent analysis. The loss on ignition is of water, which may have been chemically combined with the salts present, of carbon dioxide from the carbonates or ammonia salts, or of animal or vegetable matter. The last item is the one of prime importance, and blackening of what is otherwise a white residue is indicative of organic matter, which if of animal origin is likely to develop an offensive odor and give the analyst a clue to the nature of the contamination. The fixed residue consists of harmless or beneficial salts. A sample analysis is given below. The nature and quantity of the organic content of a water is of much greater importance. This consists of living or dead organisms of animal or vegetable nature, of fœcal matter and the products of decomposition of animal matter. There is no direct means of determining their nature and amount because in the process of determination they undergo change. But all organic matter may be burned; that is, made to unite with oxygen, and consequently the amount of oxygen consumed when water is treated with oxidizing agents is, if always determined in the same way, a guide to the relative amount of organic matter present.

More important is the fact that nitrogen is a constituent of all living matter, and its determination in the four forms in which

it may exist in water offers the best and most accurate means of study of those substances which render water unsanitary.

Nitrogen as albumenoid ammonia represents the amount of nitrogen present in the form of undecomposed organic matter. This may consist of animal tissues, urea, fœcal matter, etc., substances which serve as food for micro-organisms of vegetable or animal nature and which includes the disease bacteria. The presence of much nitrogen in this form in usually indicative of sewage pollution or drainage from refuse animal matters. The quantity is likely to be normally larger than the limits given in the preceding table where the water passes over such quantites of nitrogen bearing vegetable matter as in this region.

Nitrogen as free ammonia represents the nitrogen either as free ammonia or in combination with acid residues and which usually proceeds from nitrogenous organic matter which has decayed without the presence of considerable quantities of inorganic substances. It may be looked upon as proof of the existence of organic matter in the first stages of decay.

Nitrogen as nitrites represents the decomposition products of organic matter under the influence of living organisms, so that its presence is evidence not only of organic matter but of living germs as well.

Nitrogen as nitrates represents the complete oxidation of the nitrogenous materials, and its presence in large amount signifies that the water if not now dangerous has been so and is still open to suspicion. Indeed our work seems to show that a much smaller amount than fifteen parts per million would in this region indicate contamination.

The chlorides present in water serve for determining the purity of the water only if the location of the supply is known.

Water may contain large quantities of salt and still be free from organic contamination, though whether still good for constant consumption is a doubtful question. This is the case with water of Port Townsend. The source of the chlorine there, as is evident from the location of the pumping station, is seepage from Puget sound which of course contains large quanties of chlorides. Chlorine is however a constant constituent of urine and excrement and, other things being equal, the presence of an unusual amount of it in water is proof positive of sewage contamination.

The hardness of water is of no special sanitary importance; but since, generally speaking, the harder a water the less fit it is for domestic purposes, the relative hardness, expressed as if it were all due to calcium carbonate is a guide to the culinary and cleansing qualities of water.

The inorganic or fixed residue is never analyzed for sanitary purpose, unless the presence of some poisonous substance, as lead, is suspected. Its analysis is a guide to the usefulness of water for boiler purposes. For practical purposes the scale forming portions may be considered as made up of items 4, 5, 6, and 7 of residue analysis given below. Sometimes quantities more or less considerable of magnesium and other chlorides are present, and these are undesirable because of their corrosive action on boilers. Occasionally residue analyses will reveal the presence of ingredients of medicinal value. These will be referred to under the head of mineral springs.

RESIDUE ANALYSIS OF CEDAR RIVER WATER.

	Grams per liter (parts per thousand).
Total solids	.03117
Volatile solids	.00786
Non-volatile solids	.02331
Silica	.00178
Alumina and oxide of iron	.00492
Calcium sulphate	.00514
Calcium carbonate	.01666
Magnesium chloride	.00149
Sodium chloride	.00063

A comparison of the analyses given above reveals the fact that our cities have exceptionally pure water supplies. This is particularly true of Seattle, Tacoma, Everett, Spokane; our largest towns. They have their supplies from mountain streams and lakes which drain water sheds free from injurious contamination and to this they owe their purity.

In a country of such rank vegetable growth and heavy rainfall we would naturally expect the water to be somewhat impure. Indeed, the few analyses of surface waters made by us accord with that expection. See the analyses of wells and springs given in foregoing table.

The character of our city supplies will be sufficiently outlined by a brief description of those of Seattle, Tacoma and Spokane. Seattle obtains its supply from Cedar river at a point twenty-eight miles from the city. The river which flows into Black river is the outlet of Cedar lake, which drains an area of two

hundred square miles, all of which is under the control of the city, so that its purity is assured. The water is conveyed to the city from the intake, by gravity alone, to the high service reservoir, whence a portion is pumped by means of the surplus water to the stand pipe on Queen Anne hill, which supplies the highest parts of the city. The amount of water now conveyed to the city is about twenty-five million gallons per day, while the maximum available supply is approximately three hundred millions, a quantity sufficient to supply a population of one and a half million on the basis of one hundred and fifty gallons per capita. The reservoirs at present in use in the city have a capacity of approximately fifty million gallons.

The city of Tacoma obtains its supply from Clover creek, a small mountain stream, and from springs. These are gravel bed springs and, as is true also of Clover creek, are not affected by local rainfall. They together can furnish a maximum daily supply of twelve million gallons per day of exceptionally pure water.

Spokane obtains its supply from the Spokane river, which drains all the north and west slope of the Coeur d'Alene mountains. The supply is pumped to the city from a point about five miles above the city, and now supplies to the city about eight million gallons per day.

These supplies, because of their purity and the ease with which they are conveyed to the users, compare very favorably with that of even Chicago, which pumps its enormous supply of 160 gallons per capita per day from Lake Michigan, the purity of which in the neighborhood of the intake is improved by the sewage canal connecting the lake with the Illinois river. The local supplies are very much of an improvement over those of St. Paul, Minneapolis, New Orleans and other cities.

MINERAL SPRINGS.

The mineral springs of the state are numerous but have not been developed to any very great extent. There are hot springs at Madison on the Great Northern Railway, and at Green River Hot Springs on the line of the Northern Pacific. At both of these places sanitariums have been built and have become considerably frequented by seekers after health and pleasure. The

Madison hot springs were visited by Mr. H. G. Knight, in concection with this work, and some data in regard to them were obtained. Similar data in regard to the Green River springs were requested, but were not furnished by the owners. The Madison springs are on the mountain side just west of the tunnel on the Great Northern. The water comes out of fissures in the mountain side some six hundred feet above and a mile and a half back of the location of the sanitarium. The supply is sufficient to fill a two-inch pipe, and is at the spring at a temperature of about 112° F. The following analysis was made by Mr. C. Osseward, chemist for Stewart & Holmes Drug Company, Seattle:

RESULTS EXPRESSED IN GRAINS PER GALLON.

Total solids	9.9	Silica	1.34
Chlorine	0.87	Sodium	1.63
Iron	0.76	Potassium	0.34
Lime	2.33	Sulphuric anhydride	0.52
Magnesia	1.1	Ammonia	0.00058

There are also mineral springs at Cascades in Skamania county, which have a daily flow of thirty thousand gallons. During 1901 7,000 gallons were sold for medicinal use, and about 120,000 gallons were used for bathing purposes. A sample of the water could not be obtained for analysis in time for this report.

The waters of Medical lake in Spokane county are acquiring a reputation for curative properties, and an analysis of the water made by G. A. Mariner, of Chicago, is appended.

	Parts per thousand.
Silica	0.1825
Alumina and iron oxide	0.0120
Calcium carbonate	0.0081
Magnesium carbonate	0.0040
Sodium chloride	0.2869
Potassium chloride	0.1616
Sodium carbonate	0.1069
Potassium carbonate	Trace.
Lithium carbonate	Trace.
Borax	Trace.

Near Skykomish on the bank of the river about a half mile from the little town of Berlin, are some very interesting springs. They are saturated with carbon dioxide, and when the nearly ice-cold water is allowed to stand in vessels it effervesces vigorously. The flow from the larger of the two springs is estimated at from two to three gallons per minute. Both are chalybeate

FALLS OF THE SPOKANE RIVER, SPOKANE

FALLS OF THE YAKIMA RIVER, PROSSER.

springs and have made considerable deposits of iron around their mouths. The analysis of the water is given.

	Parts per thousand.
Solids, non-volatile	0.5478
Silica	0.0078
Alumina and iron oxide	0.0150
Calcium sulphate	0.0529
Calcium carbonate	0.5627
Magnesium chloride	0.1698
Magnesium sulphate	0.0985
Sodium sulphate	0.9881
Potassium chloride	0.0267
Carbon dioxide	1.4720

There are also mineral springs, warm and cold, in the Yakima Indian Reservation on Simcoe creek about fifteen miles from Fort Simcoe, but at the season of the year when this report was compiled it was impossible to get full information in regard to them.

By the kindness of Mr. Joseph Parrott, of Glenwood, we have considerable information regarding a rather large number of hot springs and cold mineral springs along the Klickitat river, south of Mount Adams. These seem of such interest that an effort will be made to carefully investigate them and include the report upon them in a future report of the survey.

Near Bremerton there is a mineral spring which was formerly a favorite resort of the Indians who not infrequently camped near it to obtain renewed health and vigor. Its analysis shows ingredients which render probable its medicinal value. Analysis by H. G. Knight:

	Parts per thousand.
Non-volatile solids	0.45194
Silica	0.01884
Alumina and iron oxides	0.04764
Calcium sulphate	0.046885
Magnesium chloride	0.04008
Magnesium sulphate	0.07790
Sodium sulphate	0.23686
Lithium sulphate	0.02128

ALKALI LAKES.

The alkali lakes of the state are neither numerous nor large. Among the largest are Moses lake, Blue lake and Sanitarium or Soap lake. These together with numerous temporary ponds and a chain of fresh water lakes occupy the former bed of the Columbia — the Grand Coulee.

Moses lake, which lies about twelve miles southeast of

Ephrata on the Great Northern Railway, is about eighteen miles long and a mile wide, and is very shallow. The average depth is approximately twenty feet. It lies in a shallow basin with low banks, so that a rise of but a few feet would inundate a large section of country. The water is unfit for drinking purposes, but is not strongly alkaline and could probably be used in irrigation. The section of country in which these lakes are located is, of course, very dry and supports only a scanty vegetation. Where there is water, however, the soil is very fertile. The lake drains a large area through upper Crab creek. It has no outlet but across its foot lies a low range of sand hills through which the water seeps into the sources of lower Crab creek, which occupies the bed of the canyon below. Along this canyon lie numerous shallow ponds which dry up in summer. The deposits left by these are not of any considerable value, though they contain an appreciable quantity of borax.

An interesting feature of Moses lake is the fact that it is gradually rising, having risen about ten feet in the last seven years. If it continues to rise through a few more feet it will break through a clear course into lower Crab creek and empty into the Columbia.

The analysis of the water of Moses lake is as follows. The analysis is by H. G. Knight:

	Parts per thousand.
Total solids	0.82357
Volatile solids	0.10096
Non-volatile solids	0.22262
Silica	0.01502
Alumina and iron oxide	0.00831
Calcium carbonate	0.06285
Magnesium carbonate	0.07525
Sodium sulphate	0.01258
Sodium chloride	0.01895
Sodium carbonate	0.10914

More interesting is the so-called Soap lake, or Sanitarium lake, situated about six miles north of Ephrata. This lake is so-called because it is so strongly alkaline as to be soapy to the touch, and when a strong wind blows across it the water along the shore is beaten into great rolls of foam. Fish can not live in the water, nor is there any vegetation in this as in Moses lake. The water is used for bathing, but to those unaccustomed to its use the water has a slightly caustic or irritating effect. It is also claimed that it is useful medicinally. There is much of peculiar interest about the lake. It is about two and a quarter by three-

quarters miles in extent and is very deep in places and probably averages about forty feet. It drains only a very small area of country and has neither inlet nor outlet in the form of streams. It is located in a deep basin walled to the height of one hundred feet or more on the east and west by cliffs of black basalt. The land to the north and south rises slowly; on the south to nearly the height of the cliffs, but on the north the rise is so slight that should the lake rise fifteen feet it would empty in the next of the chain of lakes to the north. The source of the water of the lake is said to be a spring in the center. The Indians of the neighborhood assert that only a few years since the lake was very small and was fed by this strongly alkaline spring. Fresh water is however continually seeping in from the shores, as is shown by the fact that fresh water wells may be sunk even but a few feet from the shore, and that the cattle disliking the strongly alkaline water face the shore to obtain the sweeter seepage. The water of the lake contains calcareous matter to such an extent that the stones and debris at the bottom are incrusted with a frost-like coating of calcium carbonate.

The analysis of the water is as follows:

	Parts per thousand.
Total solids	28.2669
Volatile solids	0.62503
Non-volatile solids	27.64186
Silica	0.12816
Alumina and iron oxide	Trace
Calcium sulphate	Trace
Calcium carbonate	Trace
Magnesium sulphate	0.39099
Sodium sulphate	6.34872
Sodium chloride	5.81884
Sodium carbonate	14.06901
Potassium carbonate	0.51177
Lithium sulphate	Trace
Phoshorus pentoxide	0.12018
Carbon dioxide (semicombined)	1.37084
Borax	None
Iodine	None
Free ammonia	.03400
Albumenoid ammonia	1.1060
The specific gravity	1.0260

A more extended investigation of the waters of the state would be of value. This is especially true of the mineral waters, which have indeed received but scant attention.

The greater part of the work and most of the analyses represented in this report are due to Mr. H. G. Knight.

ARTESIAN WATER.

BY C. A. RUDDY.

INTRODUCTION.

The fundamental principles governing the flow of artesian water are simple and readily grasped by anyone. It is only an illustration of the well known fact that "water seeks its own level." The prime requisite is to have a water-bearing stratum overlaid and underlaid by impervious strata, and to have its surface outcropping at a higher elevation than the surface of the ground where the proposed well is to be sunk. Although so simple theoretically, yet practically the problem has many factors by no means easy of solution.

Our knowledge of the conditions underlying the surface of the earth is very imperfect at best. Usually the surface outcropping of the strata are more or less obscured by a mantle of soil, so that it is often difficult to determine accurately the dip of the rocks or their exact physical structure. The ideal conditions of a synclinal valley with clearly defined strata outcropping on its elevated edges as usually figured in the text-books seldom occurs in nature; the actual conditions are not necessarily more complex, but they are more obscure.

In studying the formation of the rocks in any locality with a view to the possiblity of obtaining artesian water it is well to know just how much dependence can be placed on surface indications. Strata which at their outcrop may have all the appearances of being good water-bearers may at a short distance below the surface of the ground change into perfectly impervious strata, without in any way breaking the continuity of the beds. This change in structure may be either favorable or unfavorable, according to the other conditions of the basin. Likewise the strata above or below the water-bearer may at their outcrop be perfectly impervious and yet change in their nature so much that at the locality where the well is to be sunk they will not hold water at all.

Strata are not usually continuous over wide areas. They are more or less lenticular in shape, being usually thickest

towards the center and gradually thinning out as the edges are approached. The same bed may change from coarse to fine, from conglomerate to sandstone, and even to shale.

When the rocks of a region have been greatly folded and faulted there is not much use trying to find artesian water in them. This does not apply to long, open folds unaccompanied by fracturing, but to close folding and crushing, caused by great lateral pressure. The fact that the rocks are in such a distorted condition shows that they have been subjected to enormous pressure, which would have the tendency to compress them so much that they would lose most of their water-carrying properties. Their position, too, would usually preclude the possibility of water being carried any distance under ground. Where rocks in this condition occur it is impossible from surface indications to determine where water would likely be found.

It is useless to look for water in the older crystalline rocks, such as granite, gneiss or schist, so that when in drilling a well rocks of this nature are encountered, there is no use going any deeper.

When the drilling of a well for artesian water is contemplated, the geological structure should of course be carefully worked out as far as surface indications will permit. Very often the pervious stratum, on account of its unconsolidated or friable condition, is more easily eroded than the enclosing beds, so that it is more likely to be found in the bottom of a valley than forming the hill tops. When such a valley floor is at a greater elevation than the surface of the ground where the proposed well is to be sunk, this position of the outcrop is more favorable than otherwise, because it permits of the water being held over the surface of the outcrop for a greater length of time, and thus gives more of it a chance to soak into the rocks. The area of surface exposed of the water-bearing bed should also be taken into considration when estimating the probable quantity of water taken into the rock. The area multiplied by the annual rainfall will give the total amount of water which falls on the outcrop, but it must be borne in mind that not all the water which falls as rain soaks into the rock. A part of it runs off in the streams or is taken into the air again by evaporation. The drier the region the less the amount carried off by streams and the greater the

amount lost by evaporation. Sometimes the outcrop, as in the case of the valley mentioned above, receives the drainage of surrounding areas, and thus its available supply is augmented. The porosity of the rock at its surface will of course also have its share in determining what proportion of the rainfall is absorbed by the rocks and what escapes by other means. These considerations are of most importance in arid regions where the wells, even if succcessful, are liable to fail in time, owing to the inadequate supply.

An ordinary red brick will absorb its own weight of water. Coarse grained sandstones absorb water very readily, except where the spaces between the grains have been filled in by material carried there in solution. The finer the grains the less readily will water pass through. Fine shales and clays are almost entirely impervious, so that in an artesian basin they make a good upper and lower layer to keep the water from escaping.

The water may escape either upward or downward by means of fissures in the enclosing beds. Surface outcroppings give little indications of the existence of such defects, but in a general way it may be said that the less the beds are consolidated and the less they have been upturned from their original horizontal position, the less likely they are to be fissured. Limestones, when not fissured, are usually quite impervious, but they are more likely than any other rocks to contain underground channels, so if they form either of the enclosing beds of the supposed water-bearing stratum, they should be viewed with considerable suspicion.

Theoretically, the water should rise in the wells as high as its own head, but as a matter of fact it never does. The frictional resistance offered by the rock through which the water passes, and to a lesser extent, that offered by the walls of the well itself, has the effect of reducing the height of the column of water. The difference in height between the water in the well and at its source in the rock is greater or less depending upon the texture of the rocks, the amount of leakage, the distance the water has to come, and to a much lesser extent, the diameter of the well. Rocks of fine texture offer a very much greater resistance to the passage of water than those of coarse texture. The larger the diameter of the well the less the resist-

ance offered to the ascending column of water. The discrepancy between the theoretical height of the water and its actual height can not be accurately determined beforehand, but allowance should always be made for it. This is particularly necessary where the head is not very great.

In some of the older geological formations of the eastern states the strata are often continuous over thousands of square miles, but in this state none of the geological formations have strata continuous over wide areas. The sedimentary beds change from coarse to fine and thin out rapidly. This goes to show that it is hazardous to assume what the conditions are below the surface from the appearance of the outcrops, even a few miles away. To the practical man looking for artesian water in this state we would say, pay less attention to the character of the rock at its outcrop than to its dip. By a careful study of the dips and elevations good artesian conditions can often be discovered. Whether the rocks are pervious or impervious is largely a matter of guess work until a well has been actually sunk and the facts ascertained.

In a large number of places in the arid regions of central Washington it is not possible to obtain water for irrigation purposes by means of canals, owing to insufficient water in the streams. In these localities the only salvation lies in finding artesian water. It is perhaps too much to hope that it will be found over very wide areas, but by careful investigation new localities may be found where the position of the rocks would justify the attempt.

By referring to the chart issued annually by the United States Weather Bureau, showing the annual precipitation in different parts of the state, it will be seen that there is a large area in central Washington between the Cascade mountains and the Columbia river, and for some distance east of that stream, where the annual rainfall is less than eighteen inches. While eighteen inches per annum is usually considered the minimum amount with which agriculture can profitably be carried on, yet there are a number of conditions of soil and climate which vary this amount for different regions. Soil which is made up largely of sand or gravel or has either of them for a subsoil quickly loses its moisture and dries up. In certain parts of western Wash-

ington south of Puget sound where the annual precipitation is very heavy, there are soils of this nature on which the scanty vegetation withers up during the first few hot days of summer.

On the contrary, within the big bend of the Columbia, known as the "Big Bend Country," the soil is a deep, rich loam formed by the decomposition of the underlying basalt. The rain and snow of winter and early spring soak through the soil and fill up all the crevices of the rocks. Then when the dry weather comes these act as reservoirs and the water is gradually brought to the surface by capillary attraction and made available for the crops. In the country about Waterville, where these conditions occur, good crops are produced with an annual rainfall of about thirteen inches.

Where the rainfall is scanty it makes considerable difference how it is distributed throughout the year. To be of most use for crops the rain should come during the growing season. Where this is the case comparatively little rain will suffice.

Artesian water is of course of most value in arid regions, especially if the quantity is sufficient for irrigation. For this reason more attention ought to be paid to its exploitation in regions where the rainfall is light than where it is sufficient for agriculture. Nevertheless a good flowing well is of value almost anywhere.

YAKIMA VALLEY.

In this state the greatest progress in developing the artesian water supply has been made in the Yakima valley.

The oldest rock which outcrops in this valley is the Columbia lava, of Miocene age. It forms part of the great lava field which covers southeastern Washington and Oregon and extends southward and eastward into Idaho, Nevada and California. In Yakima county it is made up of a succession of flows varying in thickness from a few feet to a hundred or more, the line of contact between the layers being usually very well marked. Some layers show a marked difference in jointing from those above and below. The rock is a very dark basalt, usually quite compact, but often more or less vesicular. In many places beds of volcanic tuff are found between the basalt flows. Basalt, in its molten state, is one of the least viscous of lavas. When in its liquid state it is poured forth from a vent, instead of building up

FALLS OF THE SPOKANE RIVER, SPOKANE.

a cone it spreads far out as a nearly horizontal sheet. For this reason we find no volcanic cones in the Columbia lava field. Each flow found its way to the surface through a fissure which was afterwards covered up by succeeding flows. The interval of time between successive flows in this region must have been in some cases many years, and even centuries. Sufficient time elapsed for soil to form and forests to grow thereon before being overwhelmed by the next overflow. This is shown by the presence of charred wood between the flows of lava.

During the long ages in which the older rocks were becoming more and more deeply submerged by the molten flood, there was little folding or tilting of the rocks in this region. The Cascade mountains were very much lower than at present, especially in the southern part of the state. When the outflows of basaltic lava had almost ceased, there came a change, so that the region now forming the valley of the Yakima formed part of the bed of a great fresh-water lake. This lake existed so long that sediments more than a thousand feet in thickness were deposited on its bed. It was a time of great volcanic activity, as shown by the character of the sediments. These are largely volcanic ash and broken fragments of pumice. The eruptions which furnished this material were largely of the explosive type, rather than the quiet outflows which characterized the formation of the Columbia lava plain. Along the ancient shore line conglomerate beds occur, made up of boulders of light-colored andesite and other volcanic rocks. The great variations of the beds show that the oscillations of the land were comparatively rapid and irregular. Sometimes the water of the lake would recede and the streams would cut rapidly into their soft sediments; then the waters would encroach again and new sediments would be spread out, leveling off the old irregularities.

At intervals throughout the period in which the lake sediments were accumulating, there came belated outbreaks of basaltic lava which spread out over the soft sediments. These were the last convulsive signs of life of those great volcanic forces which were active throughout a great part of the Miocene period and which caused the formation of the Columbia lava fields, the greatest body of lava in the known world.

After the lake was finally drained the greater part of the sedi-

ments were carried away by erosion, but remnants still remain. They form the light-colored sedimentary beds outcropping in places in the Yakima valley and about its borders. These are the rocks in which artesian water has been found. They form what is known as the Ellensburg formation, and are of Miocene age, as shown by the fossil leaves preserved in them. The most extensive outcrops are seen along the Natches river and at White Bluffs, on the Columbia.

At the close of the period just described, the region to the westward was gradually uplifted so as to form the Cascade mountains. At the same time or later, a series of low east and west folds were formed between the Columbia river and the Cascades, nearly at right angles to the axis of the mountain range. The ridges are not due to faults, as formerly supposed; they are all anticlines, while the valleys between them are synclines. Atanum creek occupies one of these synclines, and the Natches river another. The crests of the ridges have been almost entirely denuded of the Ellensburg beds, so that only the basalt is left. One of these, known as the Selah ridge, borders the Yakima valley on the north, and another, the Yakima ridge, borders it on the south. The Yakima river has cut gaps through the ridges and crosses them at right angles. It evidently had its course established before the folding began; then as the folds arose slowly the river kept pace with them, cutting down its channel.

At some period later than the Miocene, a great stream of lava came flowing down from somewhere between the headwaters of the Nachez and Tieton rivers, covering the hills and obliterating the valleys. It reached as far east as the mouth of the Cowiche creek and then stopped. The rock is a very dark andesite. It forms a conspicuous landmark, standing as bold cliffs on the lower Tieton and at the junction of Cowiche creek with the Naches river. It is safe to say that nowhere on the surface of this lava can artesian water be found. It stands at too high an elevation, and any water contained in the beds below would find a readier outlet by means of springs along the base of the cliffs where the andesite meets the underlying rocks.

As shown by the geological map, the Ellensburg beds extend westward a mile or two beyond Tampico postoffice and occupy

practically all of the valley below that point. The city of North Yakima stands at an elevation of about 1,067 feet above sea level. Ellensburg beds have been traced twenty miles west of that point to an elevation of 2,350 feet. On the hills north of Tampico postoffice they outcrop as beds of conglomerate, sandstone and volcanic ash, dipping slightly to the eastward.

North Yakima had a total precipitation in 1900 of 7.22 inches. To the westward as the mountains are approached the precipitation increases. It seems probable that most of the water which finds its way into the strata falls upon the western border of the Ellensburg, and gradually finds its way down into the the lower part of the valley.

The two synclines occupied respectively by the Naches river and Atanum creek in their upper valleys gradually merge into one as they approach the Yakima river. Where the Yakima has cut its way across the valley there is only one syncline. On both the north and south sides, parallel to the longer sides of the valley, the beds dip towards the valley at a steep angle. On the eastern and western sides they dip more gradually. The valley is underlaid by Ellensburg beds to a depth of over a thousand feet, while along the elevated edges it has all been eroded away, leaving the bare basalt ridges.

A large part of the rain which falls on the ridges is absorbed by the rocks as soon as it reaches the porous beds at the base of the hills. Along the western border of the basin the tops of the hills are at such an elevation as materially to increase the rainfall. Atanum creek flows over the Ellensburg beds for a number of miles, and from measurements made of its volume at different places along its course, it is evident that a considerable part of it is absorbed by the rocks.

The part of the valley east of the Yakima river is known as the Moxee valley. It is here that nearly all of the artesian wells are located. There are now more than thirty wells within an area of six square miles. The following table, taken from the report of Mr. George Otis Smith on the Geology and Water Resources of a Portion of Yakima County, Water Supply and Irrigation Papers of the United States Geological Survey, No. 55, gives most of the important information concerning these wells:

LIST OF WELLS IN ATANUM-MOXEE BASIN.

Number	NAME OF WELL.	Location. Section	Township	Range	Approximate elevation	Depth	Flow	Depth to principal flows.				Temperature of water
					Feet.	*Feet.*	*Sec. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Deg. F.*
1	Clark No. 1	6	12	20	1,110	940	1.34	700	(?)	(?)	(?)	73.2
2	Clark No. 2	31	13	20	1,130	1,026	.15	800	(?)	(?)	1,000	76.2
3	Clark No. 3	31	13	20	1,120	1,000	.52	......	......	......	......	75.6
4	Longevin No. 1	8	12	20	1,070	637	.40	637	......	......	......	72.2
5	Haines	8	12	20	1,145	902	.984	702	760	790	902	72.2
6	Bradford	9	12	20	1,155	623	.904	386	......	623	......	73.2
7	Dickson	8	12	20	1,095	525	*......	515	......	......	......	70.7
8	Gano	8	12	20	1,075	851	*......	649	......	851	......	76.0
9	Sauve	8	12	20	1,155	1,020	.475	832	(?)	(?)	1,020	75.2
10	Ellens. No. 1	7	12	20	1,065	835	.13	835	......	......	......	73.2
11	Holland No. 1	5	12	20	1,100	736	†2.00	588	688	736	......	76.0
12	Regimbal	5	12	20	1,105	689	1.09	525	640	686	......	73.2
13	Buwalda	32	13	20	1,150	653	.05	424	508	550	600	67.2
14	Ellens. No. 2	8	12	20	1,100	676	*......	424	504	657	......	......
15	Buwalda and Haines	5	12	20	1,140	636	†.566	475	575	636	......	69.2
16	Holland No. 2	5	12	20	1,115	686	.35	520	620	686	......	74.7
17	Clark No. 4	31	13	20	1,140	960	.197	660	770	820	......	73.2
18	Allwardt	9	12	20	1,185	809	.64	......	615 ‡to 718	752	......	72.2
19	Deeringhoff	4	12	20	1,165	625	......	390	......	625	......	73.2
20	Rein	10	12	20	1,195	631	.485	+630	......	......	......	66.3
21	Hill	4	12	20	1,170	225	......	206	......	......	......	......
22	Longevin No. 2	8	12	20	1,080	836	.807	530	(?)	820	......	72.7
23	Peck	6	12	20	1,105	818	†1.10	620	(?)	818	......	......
24	Wilson	29	13	18	1,165	1,267	§.75	800	1,000	1,050	......	80.0

* Well closed April, 1901. ‡ Six flows.
† Approximate measurement with current meter. § Estimated.

It is estimated that the total area irrigated by these wells amounts to about 1,650 acres. Some of them are said to be decreasing in volume, and in some instances even to have ceased flowing altogether. This may be due to caving of the wells due to improper construction. It is quite possible, of course, that the basin may now be developed to its full capacity, so that the drilling of more wells would not increase the total flow. If such were the case, the water which would flow from new wells would simply decrease by that much the amount which flowed from the other wells. Heretofore the wells have been allowed to flow freely throughout the year, but at the last session of the State Legislature a law was passed compelling owners of wells to keep them closed from the 1st day of October in any year until the 1st day of the following April. This does not prevent the use of water for stock or for domestic purposes. The effect of this law will be salutary in preventing the waste of water during the season when it is not necessary for irrigation, and will greatly increase

the capacity of the basin. The amount of land in this part of valley which can be brought under cultivation is limited only by the supply of water.

On the western side of the Yakima river the demand for artesian water is not so urgent. A number of canals bring water from the Naches river, and supply all the lower part of the valley. Other canals utilize the waters of Atanum creek. Up to the present time only one artesian well has been drilled west of the Yakima. This is on the farm of Mr. George Wilson, in Wide Hollow, and irrigates about fifty acres. It is important as showing the presence of artesian water in this part of the valley, so that the problem is simplified for any one who in the future wishes to sink a well in the same locality.

KITTITAS VALLEY.

In the Kittitas valley, in which the city of Ellensburg is situated, the same geological formations occur as in the Yakima valley farther south. Its basin-like structure, however, is not so clearly marked. The valley is underlaid by the Ellensburg formation to an unknown depth. On every side of the valley the enclosing hills are of basalt. The Yakima river flows through the valley from northwest to southeast and escapes through a deep notch cut in the enclosing ridge. A well was sunk in the valley a number of years ago and is said to have reached basalt at 700 feet. Water came up within 40 feet of the surface. Mr. Smith, in the report previously referred to, is of the opinion that the chances of obtaining artesian water are sufficiently favorable to justify the drilling of another well.

WHITMAN COUNTY.

About the only other locality in the state where an artesian basin has been developed is in Whitman county. Flowing water has been struck at a number of places in the county, but the most important basin lies within the town of Pullman. This locality is within the limits of the Columbia lava field, but is not more than a dozen miles from its eastern border, where the lava lies against the flanks of the mountains of western Idaho, which are composed of ancient crystalline rocks. At several places north and south of Pullman there are isolated buttes of crystalline rock entirely surrounded by the lava, which repre-

sent the highest peaks of the ancient land surface which was submerged by the lava. Steptoe and Kamiack buttes are the most conspicuous. In Snake river canyon, a few miles to the southward, sections of the lava are exposed, which Russell* has estimated to be as much as 5,000 feet in thickness. This goes to show the extreme ruggedness of the old topography. The lava sheets have been upturned only in a very slight degree from their original horizontal position. Between some of the layers of basalt there can be seen the evidence of forest growth, showing that a considerable interval of time must have elapsed, in some cases at least, between the successive flows. In some places beds of sand occur between the sheets. These probably indicate the courses of streams which flowed over the lava during the interval between flows. The sand beds act as reservoirs for the storage of artesian water.

At Pullman there are about a dozen flowing wells in the lower part of town. In putting down these wells the drillers first penetrated a layer of basalt and finally reached sand at a depth of seventy or eighty feet. Flowing water was found in the sand. These wells have now been flowing for a number of years and do not show any diminution in volume. Besides a number of private wells, the city has one from which the whole town is supplied.

At the town of Palouse, Whitman county, there are four flowing wells. The geological conditions are the same as at Pullman. Black basalt was first penetrated and water found in the underlying sand.

It is evident that little can be foretold as to where water is likely to be found in the Palouse country. The rocks are so nearly horizontal that it is difficult to identify a basin. The beds of sand are of limited extent and usually do not outcrop on the surface. The most favorable positions for sinking wells, of course, are the lowest parts of the valleys. There is a wide extent of country where flowing waters are liable to be found. The rainfall in this part of the state is sufficient for agriculture and good non-flowing wells for domestic purposes can be found almost anywhere, so that the finding of artesian water is not of such vital importance to the welfare of the community as it is in the arid region to the westward.

* Russell: Water Supply and Irrigation Papers, No. 4, U. S. Geol. Survey.

The arid and semi-arid region of the state includes all of Douglas, Franklin and Adams counties, the eastern parts of Kittitas, Yakima and Klickitat, the western halves of Lincoln and Walla Walla, and parts of Okanogan and Chelan counties. In certain parts of this region, as in the vicinity of Waterville, farming is carried on with more or less success, but water is used for irrigation wherever it is possible to get it. By far the greater part of this arid region is very sparsely inhabited, and is so dry that it is not fit for grazing purposes, except during a few short weeks in spring. The average annual rainfall for the last ten years varies in different parts of the region from six and a half to sixteen inches. The available water in the streams is sufficient to irrigate only a small proportion of the total area, even when utilized to its fullest possible extent.

In the region west of the Columbia river, it is not unreasonable to expect that the artesian conditions which exist in the Moxee-Atanum valley may be duplicated in other places where the geology is somewhat similar. South of the Moxee-Atanum valley the country between the Cascade mountains and the Columbia is traversed by several east and west ridges similar in appearance to those to the northward whose structure has been shown to be anticlinal. If these southern ridges are also anticlines, which seems probable, the troughs between them ought to form artesian basins. Priest rapids, on the Columbia, marks the point where one of the east and west ridges has been upraised across the course of the Columbia. A careful study of the structure of these southern valleys would be necessary in order to determine whether or not it was worth the while to drill in them for water. East of the Columbia the conditions will probably be found to be somewhat different. The streams are nearly all small and have cut deep trenches in the basalt plateau. They can irrigate only small patches at best, and they usually run dry at the season when they are the most sorely needed. Where not too deeply dissected, artesian water may be found in isolated areas throughout this region in basins similar to those discovered in Whitman county.

WATER POWER.

By R. E. Heine.

INTRODUCTION.

Washington contains the greatest amount of water power of any state west of the Mississippi. The extremely heavy rainfall of the Cascade and Olympic mountains supplies the water for a large number of short, swift rivers which come tumbling down out of the mountains with a fall, in many instances, of several thousand feet in a very few miles. The Cascade mountains have been very appropriately named; everywhere along the upper reaches of the streams which head in these mountains one can see foaming cataracts and cascades alternating with stretches of more quiet water. The aggregate potential power contained in these streams is inconceivably great. The snow accumulates in the mountains to great depths in winter and melts off gradually during the summer, thus insuring a fairly uniform volume of water throughout the year.

In western Washington the greatest floods usually occur in December or the latter part of November. These are due to the heavy autumn rains which come at a season when the temperature in the mountains is not low enough to convert the moisture into snow. Again in the latter part of May, or early part of June, there are floods in all the rivers flowing down from the mountains. The floods are brought about at this time by the rapid melting of the snow during the first few hot days of summer. These floods are especially high in the tributaries of the Columbia and in that river itself. Cloudy weather during April and May, followed by a very dry, hot spell, will send all the rivers booming, and the floods are frequently very destructive. In western Washington the spring floods are not so high as they are along the eastern slope of the Cascades and in the Okanogan highlands. The climate of western Washington is more equable; there are no rapid changes from one extreme to the other, such as we find east of the Cascades, and therefore the snow melts at a more uniform rate. The streams gradually decrease in volume as summer advances until the fall rains come again. In

HEAD-WORKS OF SNOQUALMIE FALLS POWER COMPANY.

August and September they are at their lowest. All of the larger streams which head in the Cascade and Olympic ranges have at least some of their tributaries fed by glaciers. In the late summer after all the snow has disappeared from the exposed mountain sides and even the sheltered ravines, the glaciers on the highest peaks still continue to feed the streams which issue from them.

In estimating the available water power of a stream the calculations are of course based on the volume of water which the stream carries when it is at its lowest. In many cases where the stream gets too low, storage reservoirs could be built.

The Columbia river is the master stream of all eastern Washington. It has a minimum volume of about sixty thousand cubic feet per second, and in its course through the state has a total fall of about thirteen hundred feet. In a number of places along its upper course power could no doubt be taken from it. Many of its larger tributaries are rapid streams with immense undeveloped water power. In some places, as at Spokane falls on the Spokane river, and at Prosser falls on the Yakima, the power is already being utilized.

The western slope of the Cascade mountains is approximately parallel to the axis of the valley of Puget sound and its southern extension to the Columbia. This valley region is the most populous part of the state and is rapidly taking rank as a manufacturing center. Power for street railways, for electric lighting, and for all kinds of manufacturing purposes is necessary, and the problem of the cheapest way of obtaining it is one whose solution has great practical bearing upon the future welfare of the community. The great plant installed by the Snoqualmie Power Company at Snoqualmie falls will serve as an object lesson and an example of what can be done along this line. The number of places in western Washington where plants similar in kind but smaller in size could be installed is very large.

The Blue mountains lie in the extreme southeastern corner of the state. The annual rainfall on these mountains is from twenty-two to twenty-four inches. After the last of the snow melts upon their summits in the spring there is a long dry season, during which the streams get very low. For the greater part of the year, however, they possess an abundant water power which could be utilized for many purposes. Some of the streams

have already been harnessed, as in the case of Mill creek from which the city of Walla Walla derives power.

SNOQUALMIE FALLS.

The great falls of the Snoqualmie river are situated in the western foothills of the Cascade mountains, about 25 miles east of Seattle, and 34½ miles northeast of Tacoma. The river proper commences about three miles above the falls, at the junction of three tributaries whose origin is in the snow fields of the Cascades. The flow of the river is about 1,000 cubic feet per second during the driest season, and about ten times as much during the periods of high water. The river has a vertical drop of 270 feet at the falls, giving a minimum available energy of 30,000 horse-power.

The present plant is somewhat unique in its construction, inasmuch as the water wheels and electrical machinery are installed together in a large underground chamber, whose floor is directly above the tail-race tunnel which extends to the river below the falls.

A shaft 10x27 feet has been sunk into the rock about 300 feet above the falls, and at the bottom of this is excavated out of the solid rock a cavity 200 feet long by 50 feet wide and 30 feet high, and from this cavity a tunnel serving as tail-race extends to the foot of the falls.

The water is received from the river through a masonry intake and conducted down the shaft to the water wheels through a steel pipe seven and one-half feet in diameter.

The generating plant consists of four electric generators, each driven by a Doble water motor of 2,500 horse-power coupled directly to it. Two exciters of 75 kilo-watt each and one elevator operated by a water wheel complete the power equipment. The generators deliver current at 1,000 volts, which is raised to 30,000 at the transformer station above the power house.

The Snoqualmie Falls Power Company furnishes power for both lighting, railway and general power purposes, and it is expected that many of the manufacturing plants of Seattle and Tacoma will soon be operated by Snoqualmie power. At Issaquah, Renton and Auburn, power is used for lighting. In Seattle all the stationary motors, the entire municipal street-lighting system, several large mills and half of the street railways are

operated by Snoqualmie power, while at Tacoma all the lighting circuits, street railways and many motors are run from the same source.

The plant now installed develops a total of 10,000 horsepower. A transmission line to Everett, 35 miles distant, is proposed, where a smelter, paper mill and other factories are expected to be operated by electricity. By the erection of a 50-foot dam above the head works, a reservoir having an area of 15 square miles and average depth of 25 feet could be formed. This would almost double the power, should the demand call for it. The shaft will accommodate another penstock of the same capacity as the present one, and both intake and tail-race have been built for double the capacity. Another chamber and additional machinery are the only extensions necessary to double the capacity of the plant, and these have been under consideration by the company.

The Snoqualmie Falls Power Company does not engage in the distribution of power to small customers, but sells power in large quantities to customers at moderate prices. The Seattle Electric Company and Seattle Cataract Company are among the largest consumers, using nearly two-thirds of the total power generated.

SPOKANE FALLS.

Within the city limits of Spokane, and in close proximity to the manufacturing center, a series of falls are encountered by the Spokane river, aggregating a total of about 130 feet. The Washington Water Power Company owns and controls practically all of the available water power at that place, and furnishes power, either in the form of electric energy, or by leasing a part of the water supply to parties wishing to use the same.

A portion of what is called the "lower falls" is at present used for the development of power, and a number of flumes have been built from a dam 200 feet wide, situated at the head of these falls, to a power house located about 600 feet below this dam. The available head of water is 70 feet, which after reduction for height of water in the tailrace, is reduced to an effective head of 68 feet. The flumes are built of steel, of circular cross-section; two of them are each seven feet and one ten feet in diameter. The velocity of the water in the flumes is approximately six and one-half feet per second, and with the present

electrical equipment about 5,300 horse-power are carried on the switchboard.

The power generated is used for the operation of the street cars, the lighting of the street lamps, stores and private residences, and furnishing power to the various manufacturers in the city.

During the past year the Washington Water Power Company has installed two 1000-horse-power generators, one for operating the street railway system and the other for lighting and power purposes.

The conditions for development of additional water-power at Spokane are decidedly favorable. The capacity of the falls exceeds the demand. During the driest months of the year the quantity of water discharged at the falls is never less than 2,000 cubic feet per second. The present equipment of the plant utilizes scarcely 1,000 cubic feet per second, or scant fifty per cent. of the available water, which goes to show that the output of the plant can be doubled by additional flumes without increasing the head.

The Washington Water Power Company has already completed plans for the addition of two flumes, each ten feet in diameter, for the operation of a long-distance power-tansmission line to the Coeur d'Alene mining district, about ninety miles east of Spokane.

The Coeur d'Alene region is one of the great mining centers of Idaho, and the operation of the various types of mining machinery calls for a large amount of power, which has been found most suitable and flexible in the form of electricity.

The proposed transmission system is to be three-phase with a step-up transformer station at the power house, the line pressure to be 45,000 volts. Two pole lines are planned for one circuit each, copper conductors, although until the demand for power requires it, but one circuit will be put up.

By the addition of this machinery the total output of the plant will be increased to very nearly 13,000 horse-power, and will enable the company to supply light and power to parties in the vicinity of the transmission line.

In spite of the fact that Spokane is subject to considerable extremes of temperature, the Spokane river never freezes up and anchor ice is unknown, nor is the variation of head between

the tail-race and head falls very large. These two facts permit a closer regulation of the water-wheels than is the case in many water-power plants.

Should conditions demand it, the great natural reservoir, Coeur d'Alene lake, could be used as a storage reservoir, whereby the output of the plant would be increased by about 25 per cent. The Washington Water Power Company has not found it necessary to develop the power of the upper falls, which would yield an additional head of 60 feet of water. The company, however, will lease portions of these falls to parties desiring to develop their own power, or will furnish them with electric power directly, which might be a more simple proposition for an intending customer.

It is only a question of time when the manufacturing industries of Spokane will have reached a stage when nearly 20,000 horse-power will be required. The total available horse-power has been variously estimated, but in all probabilities does not fall below 30,000.

MILL CREEK, NEAR WALLA WALLA.

In the spring of 1901 the Walla Walla Gas and Electric Company completed a water-power plant for the supply of electric current to Walla Walla. The plant is situated five miles east of the city on Mill Creek, and is operated on the monocyclic system supplemented by a rotary steam engine.

Mill creek has its origin in the Blue mountains and is subject to rapid fluctations. The minimum flow is 2,800 cubic feet per minute during extreme dry weather, but the average is considerable higher.

The water is taken from the creek at a point 5,600 feet above the plant, where a concrete dam is built. The water is conveyed to the plant through a four-foot stave pipe built of redwood, the actual head at the power house being 85 feet. The pipe is buried in the ground for the entire length and has shown but little depreciation during a period of seven years.

A 27-inch Morgan-Smith turbine of 450 horse-power is directly connected at a 300 kilo-watt G. E. generator. A 400 horse-power rotary steam engine, of the Thomas and Brumagin type, is belted to generator shaft, provided with a Hill clutch, so that the generator can be operated either by water, steam or both.

The plant has been run on a 24-hour per day service since May 1, 1901, and has been in continuous operation without a single shut-down or accident.

PROSSER FALLS, YAKIMA RIVER.

The town of Prosser, in the eastern part of Yakima county, is favorably located for the development of water-power for irrigational and manufacturing purposes. Both of these have been attempted, but have not been carried out to the full capacity of the available water-power in the Yakima river. The river has a fall of about twenty feet at Prosser, and during the dry season the discharge is about 2,000 cubic feet per second, from which nearly 5,000 horse-power could be obtained.

At present the Yakima Falls Roller Mills and the Prosser Irrigation Company are the only users of water-power at that place. The former operate a small mill, using about 50 horse-power, while the latter company have already taken steps for the utilization of most of the water. A small electric light plant of 30 horse-power is also in operation, but this will be supplanted by the contemplated improvements of the Prosser Falls Irrigation Company.

This company has now in operation two pumps, each of 4,000 gallons per minute, used for irrigational purposes. Each pump is driven by a Victor turbine, forty-eight inches in diameter, capable of developing 135 horse-power, and the two combined deliver water through a 28-inch steel pipe, 2,900 feet in length, to the canal, 112 feet above the surface of the river. The irrigation canal has two branches, one three miles and the other seven miles long and is capable of irrigating nearly 2,000 acres.

The company is contemplating the addition of another pump for the purpose of supplying the city with an adequate water-works system, and an electric generator to supply the town with light and power. There is also a scheme on foot for the construction of an electric railway from Prosser on toward Yakima, the power to be generated at Prosser falls. In that event it will be necessary to either build a dam to increase the fall, or to go some distance below the falls in order to obtain sufficient head of water, as the present pumping station is worked at a head of only twelve feet.

The prospects for an increased demand of power and water

at Prosser and vicinity are very favorable, a larger electric lighting plant being now almost a necessity. The Prosser Falls Irrigation Company controls the entire south side of the river, on which the town is situated, and is prepared to install machinery for parties contemplating the use of power.

CHELAN FALLS.

One of the large and still undeveloped sources of water-power of the state can be found in the Chelan river, which is the outlet of Lake Chelan, and flows into the Columbia river. The river is about three and a half miles long from Lake Chelan to the Columbia river, the total fall being 375 feet, distributed through the whole distance in a series of rapids and low falls. About one-third of the total fall occurs within a distance of half a mile, where the river flows through a box canyon. It is only thirty or forty feet wide in places, rushing down between rocky walls 300 feet high.

The cliff recedes at one point, leaving ample room for a large power station. In the two and a half miles from the lake to the canyon, the fall is quite regular, and power plants could be located at many places. The only existing plant at present is a 40-barrel flour mill at Chelan falls near the mouth of the river.

No accurate measurements of the water supply have been made, except those of some local parties, which show that the minimum flow is from 1,200 to 1,500 cubic feet per second.

The Chelan Transportation and Smelting Company expect to erect an electric plant very soon, the capacity of the plant to be about 500 horse-power. This plant will be used for the operation of their smelter and an electric railroad from the smelter, situated on the Columbia river, to the lake. The company expects to have the cars in operation during the latter part of 1902. The chief use of the railroad will be the transportation of ores from the numerous mines in the vicinity to the smelter, the capacity of which will be about 500 tons per day.

There is a good opportunity for flouring mills to be operated by water-power, the wheat crop of the entire "Big Bend country" being at their very doors.

Irrigation can also be developed to a considerable extent, there being over 3,000 acres of land waiting for water. All that is required is the necessary capital for the operating plant.

As mentioned before, no thorough investigation of the resources of water-power have been made at this place, and one can safely predict an industrial center at Chelan should the same ever be developed to the full capacity.

PURITAN MINES, NEAR LOOMIS.

The Puritan mines are situated on a stream known as Toats coulee, a rushing mountain torrent, which encounters a fall of about 300 feet within the located water right of the mining company. At the lowest stage of water the supply is sufficient to develop fully 1,000 horse power, which would be ample for all necessary mining and milling operations on their property.

At present two Pelton water wheels are installed, one driving a 50-horse-power Ingersoll compressor, and the other operating a saw-mill utilizing about 60 horse-power.

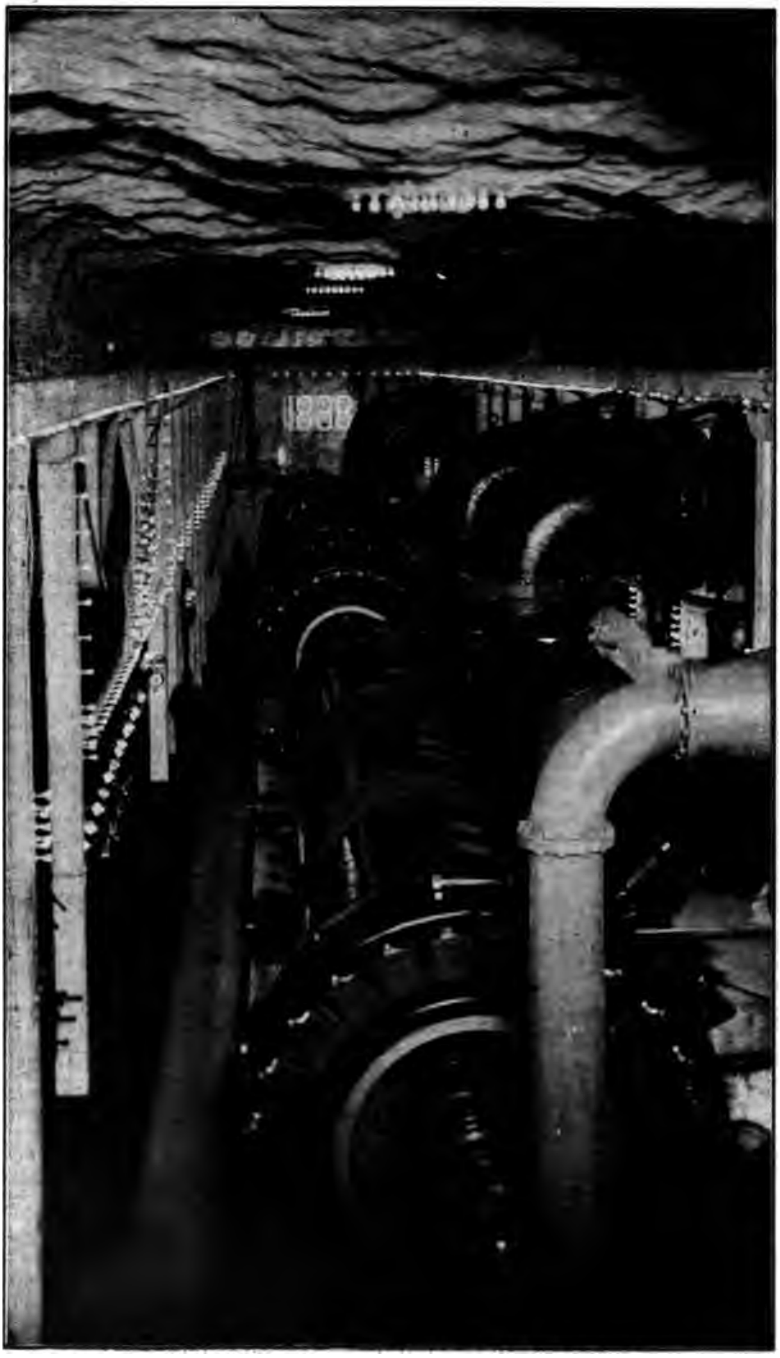
Future developments in the mining and milling industries at this locality might make the development of additional water power necessary, for which, however, there is an abundant supply in the stream mentioned above, the total head of water which might be utilized being nearly 1,000 feet.

WHATCOM FALLS.

Lake Whatcom, having an area of about eight square miles, is situated nearly three miles from Bellingham bay, and its mean elevation is about 318 feet above tidewater. Whatcom creek, the outlet of the lake, empties into the bay in the city of Whatcom. The water-power of this creek consists of three main falls, the first occurring about half a mile from the lake, the next half a mile below this one, and the last just before the stream enters Bellingham bay. This last fall is now developed and is used for the operation of a large lumber mill.

For the first two miles the stream is very rapid, the banks steep and the average width of the stream not over forty feet. The river bed shows in many places to be of solid rock, and ought not to add any difficulties for the foundations of any power plants. The total head of water from the lake to bay is about 318 feet, of which 150 feet occurs in the upper two falls.

No accurate measurements of the amount of water discharged have ever been taken, but rough measurements by various parties show that the minimum flow is about 140 cubic feet per



INTERIOR OF SNOQUALMIE FALLS POWER STATION.

second. The watershed which drains this lake contains no less than sixty square miles. By building a dam at the outlet of the lake, which can be done without great difficulties, the level of the lake might be increased four or five feet, affording an excellent means of storing water during the wet months, to be available during the dry seasons, and amply sufficient to sustain a minimum flow of 150 cubic feet per second.

With an effective fall of 200 feet a total of 2,400 net horse-power can be relied upon at all times, this being more than will be required to meet the demands for a number of years.

At the present time the creek supplies the city of Whatcom with water, and is capable of furnishing a total of 25,000,000 gallons per day.

Various propositions for the development of this power have been made from time to time. Perhaps the simplest scheme would be to develop the power nearest the city first, which would furnish about 1,200 horse-power, and later, when a greater demand for power will exist, develop the rest of the falls.

NOOKSACK FALLS.

The Bellingham Bay & Eastern Railway, operating a steam railroad in the northwestern part of the state, has undertaken to develop the water-power of the falls of the Nooksack river. The falls are situated fifty-two miles, by rail, from the city of Whatcom, and fifteen miles beyond the present terminus of the road. Active work on the construction of a large power station has already begun. The power-house is to be located 1,500 feet below the falls, whose vertical height is 103 feet. The intake will be about 250 feet above the falls, and a large tunnel is being excavated. By so locating the power station an effective head of water of 179 feet is obtained; this with the amount of water being capable of developing a minimum of 10,000 horse-power. On account of the difficulty of handling material, three steel pipes, each thirty inches in diameter, will be run to the power-house instead of one large one; this will also permit the operation of a part of the plant as soon as the machinery is installed. All the power will be converted into electric energy. The transmission line is planned along the right-of-way of the railroad. The company expects to supply the Great Excelsoir Mining Company, located close by, as well as the rest of the mining

properties in the vicinity, with power. An electric railway into the mining districts is also to be operated from the falls, and ultimately a line supplying the Bellingham bay cities with light and power, is to be constructed.

TUMWATER FALLS, NEAR OLYMPIA.

About two miles south of Olympia, at what is known as Tumwater, are a series of three falls in the Deschutes river, aggregating a total fall of about 78 feet. The flow of water is somewhat variable, being about eight times greater during February and March than in July and August. There is at present a power station built at that place, utilizing the water of the upper falls, or an effective height of 46 feet. The construction of the plant is in brief as follows: From a retaining wall a flume, 10 feet square on the inside, has been built toward the lower fall. A tap, eight feet square, is taken from this to the power house and operates two pair of 25-inch and one pair of 17-inch turbine wheels, capable of developing about 1,200 horse power. During the dry months, however, the supply of water is not sufficient to operate all of these at full load. The present output of the plant averages about 800 horse power, which is used for lighting, power and street railway purposes.

In order to obtain the most out of the available water power it should be developed all at one fall and in one power house. By building a storage pond at the upper fall, and with proper allowance for low tide, an effective fall of 48 feet could be obtained. This will require a good deal of blasting of rock, especially at the lower falls, inasmuch as the river bed is composed entirely of solid rock. The table below shows the discharge of the falls and horse power obtained at 84 feet fall.

MONTH.	*Cu. ft. per sec.*	*H. P. at 84 ft.*
January	781	5,580
February	1,060	7,550
March	1,040	7,400
April	692	4,900
May	416	3,000
June	251	1,800
July	120	860
August	104	740
September	142	1,010
October	357	2,540
November	634	4,500
December	925	6,600

During the three driest months the available power would be

somewhat below 1,000 horse power, but for the rest of the year it is safe to assume it at 3,000. Inasmuch as the lightest load would fall upon the plant during the summer months, the capacity of the plant might be rated at 3,000 for the entire year by the addition of a small supplementary steam plant.

The present plant is the only one operated in that vicinity, and has, up to this time, been able to meet all demands for electrical power.

CARBON RIVER AND EVANS CREEK, FAIRFAX.

In the vicinity of Fairfax, Pierce county, are situated several mines utilizing water power to a great extent, and in a way which might serve as a model to many mines in similar positions.

The Montezuma Mining Company operates several mines and a lumber mill about two miles from Fairfax and utilizes the water power of Evans creek, a small mountain stream, to its full capacity. The water is brought to the entrance of the mines in a wooden flume 3x4 feet, where it has a vertical effective fall of 89 feet through a penstock, operating a 350 horsepower turbine. A two-horse-power blower is also operated from this fall. The power developed is used for the operation of the saw-mill, a small machine-shop and the machinery in the coal-bunkers. A 15-horse-power dynamo furnishes electric light for the mine and shops. An air compressor, used to furnish power for the mine drills, is driven by the same turbine. The water, after it has left the turbine, is diverted into two shallow flumes, used for coal and lumber respectively. The latter are flumed from the bunkers and mill for a distance of three-fourths of a mile, where they can be loaded on railroad cars. The plant has been in operation for some time and been running very satisfactorily; it being unique in the way that the full amount of power being utilized for the operation of the most varied kinds of machinery, electric lighting, saw-mill and coal handling and compressed air machinery, all being run from one small creek.

The Western American Mining Company, very near Fairfax, has partially utilized the water-power of the Carbon river. Owing to the absence of any appreciable fall in this river a flume 8x4 feet has been built, extending up along the river for about one mile. A penstock, giving a vertical fall of 47 feet, is

built above a 300-horse-power turbine, operating a 200 kilo-watt generator. This generator furnishes power for ventilating the mine, operating the electric locomotives, the coal bunkers, coal-handling machinery and machine-shop, and also lights the town of Fairfax and the mines proper.

An additional installation of a 250-horse-power turbine will be made shortly, although at present the water supply at its lowest stage is not quite sufficient to operate both turbines at one time.

INDEX.

WASHINGTON

GEOLOGICAL SURVEY.

HENRY LANDES, STATE GEOLOGIST.

VOLUME I.

ANNUAL REPORT FOR 1901.

IN SIX PARTS.

PART VI.

BIBLIOGRAPHY OF THE LITERATURE REFERRING TO THE GEOLOGY OF WASHINGTON.

BY

RALPH ARNOLD.

THE SEAL OF THE STATE OF WASHINGTON 1889

OLYMPIA, WASH.:
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1902.

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PREFACE.

The Bibliography of the Literature Referring to the Geology of Washington was written chiefly by Mr. Ralph Arnold, of Stanford University. After the manuscript was received from Mr. Arnold, a number of references were added by Professor Milnor Roberts. This bibliograpy has been prepared with great thoroughness and care, and it is believed to be practically complete. While many of the articles are out of print, or else are to be found only in the larger libraries, it will be noticed that the most important papers mentioned are of a late date and as a rule easily procured. Professor Roberts has prepared brief notes upon some of the articles, stating the substance of their contents, where they may be secured, cost, etc. It is hoped that this bibliography of Washington geology, the first to be prepared, may be found useful to all students of the subject.

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BY RALPH ARNOLD.

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